Florida Department of Transportation
Office of Maintenance

Bridge Maintenance & Repair Handbook

October 2019

CHAPTER 1

DECK EXPANSION JOINTS

1.1 JOINT TYPES

A variety of devices have been incorporated in the design of bridge deck expansion joints. Some of the devices have been effective while others have performed poorly. Joints can be classified into two classifications - open and closed. Closed joints are designed to be waterproof, while open joints are not.

1.1.1 Open Joints

Open joints can be found on older structures. Drainage systems are often installed to carry away water runoff from the joint. Common types of open joints and their normal opening widths include:

A. Butt Joints (1 in.)

Armoring is usually provided. See Figure 1-1. The joint will often fill with non-compressible materials and thus become inoperable. When used with asphalt overlays, the armoring should extend to the surface elevation of the overlay. A joint transition dam is required to achieve this; otherwise, raveling of the wearing surface can occur at the joint. Normal maintenance includes periodically clearing the opening of roadway debris, painting, and repairing the roadway surface adjacent to the armor plate or dam.

B. Sliding Plate Joint (1 in. to 3 in.)

Plate joints are difficult to maintain. It is common for plates to become loose, indicated by a loud noise as traffic crosses, and occasionally to become completely detached, which results in a safety hazard. There are several reasons for this depending on the particular design, although much of the problem can be attributed to the inadequate consolidation of the concrete under and around the plates. The anchors also corrode and are subject to fatigue from the continuous pounding of traffic. Sometimes the roadway surface around the plates deteriorates, increasing the impact from traffic on the joint, and dislodging the plates. Buildup of debris in the joint will often prevent the joint from functioning. See Figure 1-2.

C. Finger/Tooth/Cantilever Joint (3 in.)

Finger joints operate well when properly maintained. Maintenance requirements are similar to those required for sliding plate joints. Drainage troughs are almost always placed under finger joints. See Figure 1-3.

1.1.2 Closed Joints

Closed joints are designed to be watertight and include the filled butt joints, compression seals, membrane joints, cushion joints, and modular joints.

A. Filled Butt Joints (1 in.)

A filled butt joint is similar to the open butt joint already discussed. A pre-molded joint material is usually attached to one face of the joint or supported from below by an offset in the vertical face of the slab. A sealing compound (either poured rubber or silicone) is poured from the roadway surface to seal the opening. See Figure 1-4. Maintenance requirements include periodic cleaning, replacement of the surface seal, replacement of the filler, and repairs to the roadway surface adjacent to the joint. Poured-in-place seals work best when movement is less than 1/2 inch. A quality joint may last only 2 years. Inspectors have observed both cold-poured and hot-poured seals leaking after being in place less than 6 months. Power cleaning of the concrete surface prior to placing the seal improves the adhesion. If this type of joint is not kept watertight, the filler below will deteriorate and make resealing difficult. Non-compressibles that work their way into the seal can cause the joint to jam.

B. Compression Seals (2 5/8 in.)

Compression seals generally have performed very well. See Figure 1-5. It is critical that the opening be dimensioned properly for the seal because it is squeezed into the opening so that it expands and is compressed with the joint movement. It will separate from the deck in cold weather if the opening is too large. If the opening is too small, the seal will be damaged by the compressive force in hot weather. If the opening is too small or the seal is placed too close to the surface, it will be damaged by traffic in hot weather as it bulges due to compression. A particular problem with these seals is the cutting necessary to make bends around curbs and parapets. See Figure 1-6. Compression seals can be used for large movements when multiple units are used. Maintenance requirements for compression seals are minimal. Periodic cleaning and roadway repair are all that is normally required. When evidence of leakage is discovered, steps should be taken to correct the situation by repair or replacement of the seal.

C. Membrane Joints (4 in.)

Membrane seals, also known as strip seals, consist of a flexible sheet of neoprene rigidly attached to two metal facings cast into the facings of the joint. The material is bent in the shape of a “U” and flexes with the movement of the bridge. See Figure 1-7. When properly installed these joints are very watertight. Problem areas are at gutter lines and areas where breaks in the cross section occur. Breakdown of the membrane usually occurs as the result of non-compressible material being lodged in the joint when the opening is expanded. As the joint closes, these materials become wedged in the membrane and can cause a rupture with loss of water tightness of the joint. Breakdown can also occur as the result of traffic movement over debris-filled joints. Maintenance requirements include periodically removing debris and sealing or replacing defective membranes. As with compression seals, these units can be used in multiple units.

D. Cushion Joints (4 in.)

The cushion seal is made up of a reinforced neoprene pad that is rigidly attached to each side of the joint. See Figure 1-8. The inherent characteristics of the material permit it to expand as the joint opens and to shrink as the joint closes. One of the more difficult problems in maintaining these joints involves the anchorage system. Details at the curb line are also particularly troublesome. Improper design or installation can create a continual maintenance problem. Another problem is that units are normally provided in nominal increments of length and thus require field splicing. Splicing is difficult to do to ensure long-lasting maintenance-free service, especially when subjected to heavy traffic. Caps that seal the anchors are usually installed with an adhesive. Adhesive is also used at the interface between the cushion and the concrete to maintain water tightness. The adhesives routinely breakdown and result in the loss of caps and leakage of the joint. Maintenance requirements include periodic cleaning, inspection of the anchoring devices, replacement when required, and repair of the seal.

E. Modular Joints (4 in.)

Modular dam deck joints are fabricated to accommodate larger movements, over 4 inches. They are special designs consisting of a series of strip or compression seals separated by beams and supported by a series of bars. See Figure 1-9. They are designed so that components can be removed and replaced.

1.2 PREVENTIVE MAINTENANCE

Preventive maintenance of bridge deck expansion joints is vital to maintaining the serviceability and prolonging the life of a bridge. Preventive maintenance usually means cleaning the joint. Preventive maintenance is most effective if it begins when a bridge is new and continues throughout the service life. The objective of preventative maintenance for deck joints is keeping the seal securely in place and waterproof. This starts when the joint seal is installed. Too often, seals are installed improperly and were never watertight. Construction inspectors and maintenance workers must understand the importance of, and the proper installation procedures to achieve watertight joints. Common mistakes include:

1.2.1 Casting the Joint Opening Improperly

The opening must be the proper width at the designated temperature and the sides must be vertical, straight, and parallel.

1.2.2 Placing the Seal Too High

The seal should be properly recessed, so that when the deck is expanded in the hottest weather, as the joint closes, the seal is not compressed above the grade of the deck. Normally, this would mean recessing the seal 1/4 to 3/8 inch. However, on the wider compression seals this may not be enough; therefore, manufacturer's specifications should be followed.

1.2.3 Damaging the Joint Edge During Construction

Seals are not effective if the edges of the joint are damaged during construction. During the finishing operation, the edges should be smoothed and rounded with a 1/4 inch radius. Joints should be protected while the concrete is green. Under no circumstances should steel-wheeled equipment be permitted to cross an unprotected deck.

1.2.4 Poor Bond to the Concrete

The most important part of achieving a good bond is proper cleaning of the joint prior to placing the steel. This is most important on existing decks that have an accumulation of dirt and oil products on the surface. The most effective method of cleaning the surface is by sandblasting.

Most seals rely on an adhesive to help achieve a bond to the concrete. This adhesive should be properly applied and not permitted to dry before the seal is in place. The poured sealers have adhesive properties within the material.

1.2.5 Poured Seal Must Stretch

Poured seal should be bonded on the sides, but not the bottom of the opening. If the seal is bonded to the bottom, there is insufficient distance for it to stretch and it will crack. A bond-breaker should be placed on the bottom if the seal rests on concrete or if a filler material is used. Poured seal should be thin enough to stretch or the resistance of the material will break the bond and pull it apart from the sides. Ideally the width is greater on the sides where bond is needed and less near the center so that it can stretch. Figure 1-10 illustrates correct and incorrect hot-poured sealer installation.

1.3 SPECIFIC JOINT PROBLEMS

A number of joint problems occur routinely, including edge and surface damage as well as structural breakdown. Descriptions of these problems and some suggested repair techniques are discussed in the following sections.

1.3.1 Edge Damage

Excessive edge pressure on the concrete at any time either during or after construction, as caused by crossing the deck with steel-wheeled rollers or steel-track equipment without adequate protection, may cause this damage. Irregularities in the grade of the deck between the two spans will also contribute to edge failure.

The width of the damaged area around the joint and other maintenance and repair work needed on the bridge will influence the method used to correct this damage. If the damaged area is narrow and the remaining concrete of the deck is sound, the joint may be widened by saw cutting and adding a compression seal. A more durable solution, particularly if the joint must be recast, is to add an armored device to reinforce the edge of the concrete. Attempts have been made to repair a damaged edge with cement or epoxy mortar, but this type of repair is not durable, particularly if the feathered edges are not eliminated by saw cutting.

1.3.2 Armored Angle Joint Repair

Armored angle joints that have sustained damage to the anchor pins or have minor spalled concrete below the angle should be repaired as follows. See Figure 1-11.

A. Recommended Repair Method:

1. Remove seal from joint.
2. Angle drill armor plates at 45 degrees with special recess bit 82 degrees. (Requires magnetic drill mount.)
3. Drill 45 degrees through concrete deck with coring unit using rebar eater and diamond core bits.
4. Install under cutting tool for wedge anchors and drill out bottom anchorages area.
5. Install maxie bolt assembly with proper setting tool. "Torque in place".
6. Torque in place special angle fasteners.
7. Tack weld fasteners, grind finish, clean armor angle, and paint surface area.
8. Drill access holes on top of armor angle. Inject polyomertic concrete throughout voids where they exist.

1.3.3 Armored Angle Joint Replacement

See Figure 1-12.

A. Recommended Method

1. Remove steel dams and supports as necessary by cutting anchors or dam with cutting torch.
2. Remove unsound concrete by saw cutting and jack hammering.
3. Place forms for concrete and anchor system for dam.
4. Set dam in place.
5. Place and finish concrete.
6. Complete assembly of dam or remove temporary shipping and erection braces as necessary.
7. Place new neoprene compression seal, drainage trough or water collector as necessary.
8. Welding details for this repair should be furnished by a qualified engineer and the welding should be accomplished

by personnel certified for the type and position of the weld required.

1.3.4 Raveling of the Wearing Surface Over a Joint

It has been common practice to pave or seal coat over a concrete deck with a bituminous wearing surface, thereby completely covering and obscuring the deck joints. This temporarily hides joint problems while improving the riding surface, but the deck movement causes cracking and raveling of the surface at the joints. The wearing surface prohibits inspection and maintenance of the joint.

If wearing surfaces or overlays are required on a bridge, the joints should be redesigned to accommodate the change. The joint opening may be continued to the elevation of the new surface by adding joint transition dams. When, however, the dams are constructed prior to the placement of the new overlay or wearing surface, it often results in a rough-riding transition. This may be avoided by placing the new surface, ignoring the joint, and then removing the material over the joint. The top of the dam should be installed to match the grade of the new surface.

1.3.5 Loose Sliding Plate Joint

It is common for steel plates to become dislodged from the anchoring system. Because sliding plate joints are not watertight, repairs often include replacing the joint with a waterproof seal. This can be done by adding a lip to hold the seal in place, injecting epoxy to fill the voids, or removing and replacing a portion of the deck around the joint. When replacement is not practical, loose sliding plate joints can also be repaired. See Figure 1-13.

A. Recommended Method

1. Burn hole through top flange of expansion plate as needed. Treat all areas burned and welded with corrosion protectant - several coats of cold galvanizing compound.
2. Drill 1 1/4 inch hole at a 45 degree angle into concrete deck below the burned hole. Avoid damaging reinforcing steel as much as possible.
3. Fill hole with epoxy type material for anchorage; self locking bolts may be used.
4. Place bolt in position and weld to top flange of plate with full penetration weld. Clean and treat area with corrosion protectant.

5. Drill at top flange close to bolt location, or where void may be detected and fill with liquid epoxy as needed.
6. Remove fittings and plug, seal, and grind smooth top of plate.

1.3.6 Deteriorated Joint Filler

Pre-molded joint fillers frequently deteriorate or become loose and fall out of the joint. Repairs should include removal of all joint material followed by a thorough cleaning of the opening. An alternate replacement is the compression seal. See Figure 1-14. This may require removal of a portion of the deck and recasting to accommodate the joint armor and anchorage. All joints of less than 1 inch, having limited movement, can also be accommodated by replacing with the poured silicone joint sealant.

A. Recommended Method

1. Clean joint of all existing sealer and backer material using a plow. Do not move joint filler unless it is deteriorated. If necessary, re-saw joint to the desired width.
2. Remove all sealer material from the joint faces by using wire brushes and remove all loose material from the joint by air compressor.
3. Place foam joint backing material into joint and push down approximately 3/4 inch below the deck surface. The backing material should be approximately 1/8 inch wider than the joint.
4. Pour sealant into joint to keep the vertical drop from the deck surface within 3/8 inch.

1.3.7 Anchorage Failure on Cushion Joints

One of the major problems with use of elastomeric cushion seals is the failure of the anchoring device and the subsequent loss of the seal. The voided areas may have been filled with bituminous material as a stopgap repair. Ultimately, a new elastomeric cushion must be installed or the entire joint must be replaced.

1.4 UPGRADING JOINTS WITH COMPRESSION SEALS

Currently the compression seal is most often used to upgrade the poured-in-place seals commonly found on older bridges. Installation is made in either a sawed or a formed concrete joint opening. See Figure 1-14. The success of the seal is greatly influenced by the condition of the opening that is provided. It must be properly sized and the sides must be vertical, parallel, straight, and clean.

Temperature considerations are vital in determining the proper dimensions between the joint faces when forming or sawing the joint opening. The expansion movement of the deck will be restricted if the joint is too narrow. If it is too wide, a greater than required opening will occur in extreme cold, resulting in the possible separation of the joint material from the joint face. The following table should be used to determine the width of the saw cut at the mean temperature for a geographical region:

Exist. Joint Width	Width of Saw Cut	Size of Joint Seal
1/2 in.	1 in.	1 9/16 in.
1 in.	1 1/2 in.	2 1/4 in.
2 in.	2 5/8 in.	3 5/8 in.
2 5/8 in.	3 in.	4 in.
3 in.	3 5/8 in.	5 in.

Installation consists of compressing and inserting the joint material into the joint opening. Insertion is facilitated by the use of a lubricant adhesive, which will provide filler between the joint face and the joint material, and produce a bond of sufficient strength to maintain a waterproof seal between the deck and joint material.

The compression joint material should be inserted into the joint while the adhesive is still slippery, so that the top of the web of the compression seal is at least 1/4 inch, preferably 3/8 inch below the deck surface. The concrete edges should be beveled 1/4 to 3/8 inches to reduce breaking at the corners of the deck joint.

Other types of joints generally require the cutting off of sufficient pavement so that the new joint system can be anchored to the reinforcing steel. The concrete is then formed and poured to complete the deck and the new joint. The installations are generally accomplished during a major deck rehabilitation project. If an overlay is placed on a bridge deck, this is a good time to upgrade the joint with a compression seal.

1.4.1 Application

Used to seal open joints, reseal joints where preformed joint material has failed and to reseal joints that have failed which were originally sealed with elastomeric compression seals. The existing concrete joint must be sound with no edge raveling; otherwise, the concrete edge of the joint must be repaired.

1.4.2 Deck Area

A. Recommended Method

1. Determine size of joint material required and have on hand before beginning operation.
2. Clean joint as necessary. If joint contains compressed debris or preformed joint material, a high pressure water jet may be required to clean joint.
3. Saw cut joint to uniform dimensions across bridge deck to the predetermined width and depth.
4. Clean dirt, debris, stones or standing water from the joint using compressed air.
5. Apply adhesive/lubricant to the face of joint.
6. Position seal over the joint opening and compress bottom portion of the seal and insert into joint while the adhesive is still effective as shown in Figure 1-14.
7. Complete installation by positioning seal within the joint to a depth required, usually 1/4 to 3/8 inch below the deck surface.

1.4.3 Curb & Median Area

A. Recommended Method

1. Locate 1/2 inch diameter hole and drill through seal by using a standard twist drill.
2. For upturn location, cut lower section of seal to 1/2 inch diameter hole by using a sharp, long blade knife.
3. For downturn location, construct two lines to form a triangle below the 1/2 inch diameter hole and cut along 45 degree sloped lines to remove triangular shaped piece of seal as shown in Figure 1-6.

4. Bend seal in desired shape and install into the joint in accordance with the normal performed compression seal installation procedure.

1.4.4 Compression Seal with Asphalt Overlay

For repairing expansion joints that have been overlaid with asphalt. See Figure 1-15.

A. Recommended Method

1. Saw cut asphalt across deck one foot each side of joint.
2. Remove asphalt and thoroughly clean concrete deck.
3. Place filler in joint to form area between joint and asphalt.
4. Coat cleaned concrete surface with epoxy bonding compound.
5. Place and finish off latex modified concrete flush with existing asphalt.
6. After concrete has set, saw cut to required width and depth for seal to be installed.
7. Clean dust from joint, lubricate with adhesive and install seal as specified above.

1.4.5 Joint Replacement Using Armored Compression Seal

To replace an existing defective expansion joint with a new armored compression seal joint:

A. Recommended Method

1. Cut or remove sliding plate or other joint.
2. Place new armored joint and reinforcing.
3. Place concrete around joint or overlay deck as required.
4. Place preformed neoprene compression seal.
5. See Figure 1-16.

1.5 CONSEQUENCES OF POOR MAINTENANCE

It is mandatory to design, install, and maintain waterproof joints in order to preserve other portions of the structure. The following are some of the problems that can develop when deck joints are not adequate or maintained properly.

1.5.1 Damaged End Diaphragms

Normally the first members to show discoloration due to rust are the end diaphragms on bridges with painted steel superstructures. Moisture and salts that pass through the joints cause the rust. Section loss will occur in the steel if the corrosion is permitted to continue. The corrosion of the top flange of the diaphragms expands the metal, which also causes the deck to rise. This not only results in an irregular riding surface, but in time causes transverse cracking in the deck near the joint.

Reinforced concrete diaphragms are slower to show problems than steel diaphragms. The moisture penetrates the concrete and corrodes the rebars. This causes spalling of the concrete and section loss of the reinforced steel.

The practice of designing a drip edge on the bottom of the deck between the joint and the diaphragm has been used to try to eliminate this problem.

1.5.2 Damaged Beam Ends

The beam ends are affected in a manner similar to the end diaphragms. Paint systems normally break down more rapidly in this area, and corrosion damage is worse than elsewhere on the beams. On bridges where the joints are not kept watertight, the time period between necessary repainting and repairs of the superstructure elements is greatly reduced.

1.5.3 Damaged Bearings

When joint leakage occurs, the bridge bearings are exposed to moisture and debris that in turn cause deterioration and corrosion. Often the bearings that were designed to accommodate the superstructure movement will become frozen due to corrosion. Because of this, the bridge is subjected to stresses not accounted for in the original design.

Serious problems in members such as beams, seats, or substructure supports can therefore result. Often a concrete beam will develop a diagonal crack that begins on the bottom of the beam at the end of the bearing and extends back and upward from the bearing. The force may also cause the seat to crack. When bearings become frozen, movement is transferred to other bearings, which causes joints to jam or open excessively.

Movement transferred by frozen bearings may also cause adjacent bearings to tilt or slide beyond their design limits. The pressure created by the frozen bearings has been known to cause substructure columns to crack or tilt. On skewed bridges, frozen bearings can cause the superstructure to be forced out of alignment.

1.5.4 Damaged Seats and Caps

Leaking joints are commonly evidenced by discoloration of the sides of the substructure. Moisture, salts, and debris that spill through the joints tend to accumulate and pile up on the seats and the top of the caps. The debris holds moisture, which keeps the area constantly damp. The result is that the moisture and salt deteriorate the concrete at an accelerated rate and penetrate to the reinforcing steel. The bearing areas are in turn damaged by the disintegration of the concrete.

1.5.5 Embankment Erosion Drainage

Water leaking through joints at abutments can cause erosion of the soil embankment. If no provisions are made to check this erosion, it can undermine the footing and expose the piles.

Figure 1-1
Butt Joint

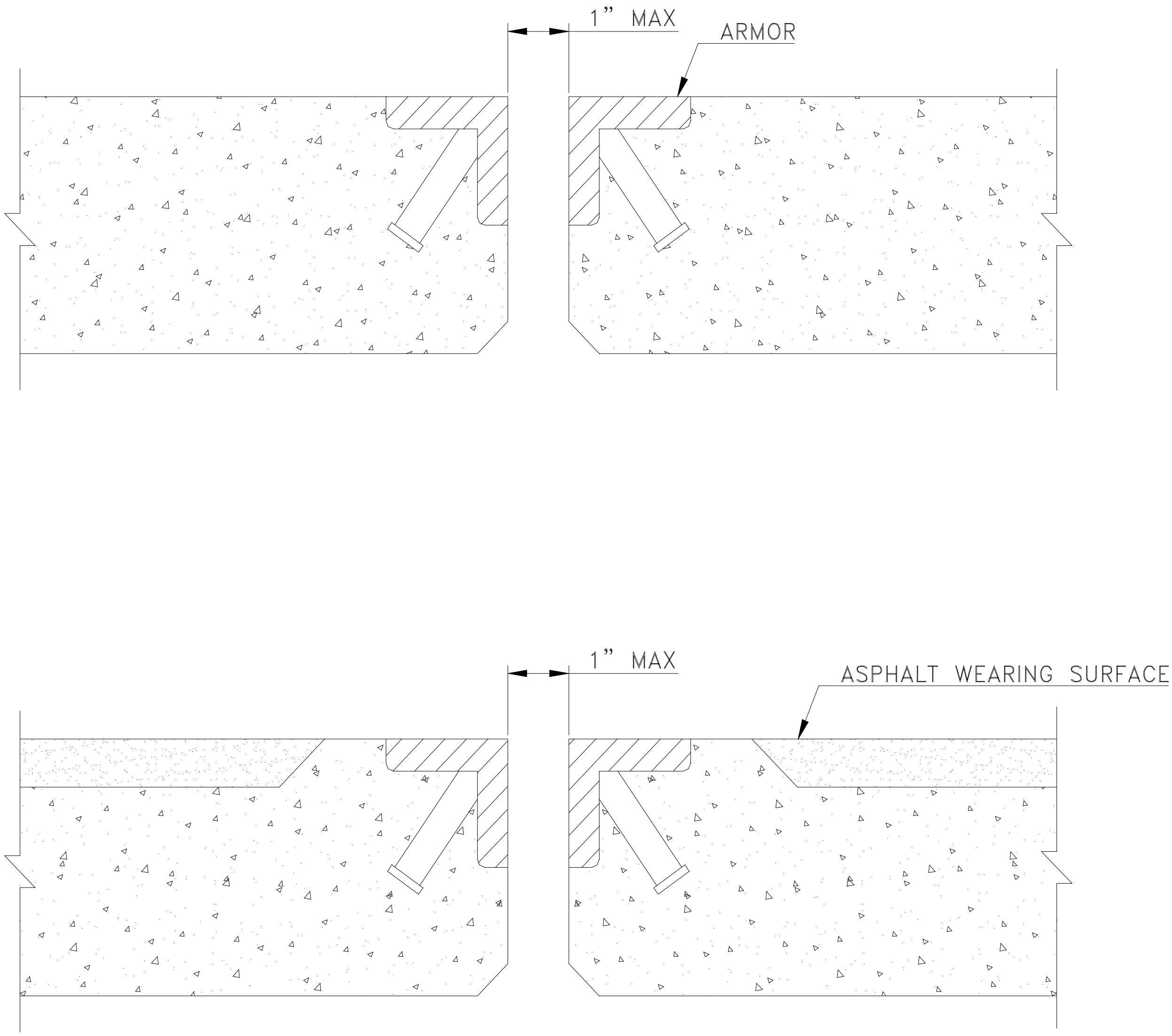


Figure 1-2
Sliding Plate Joint

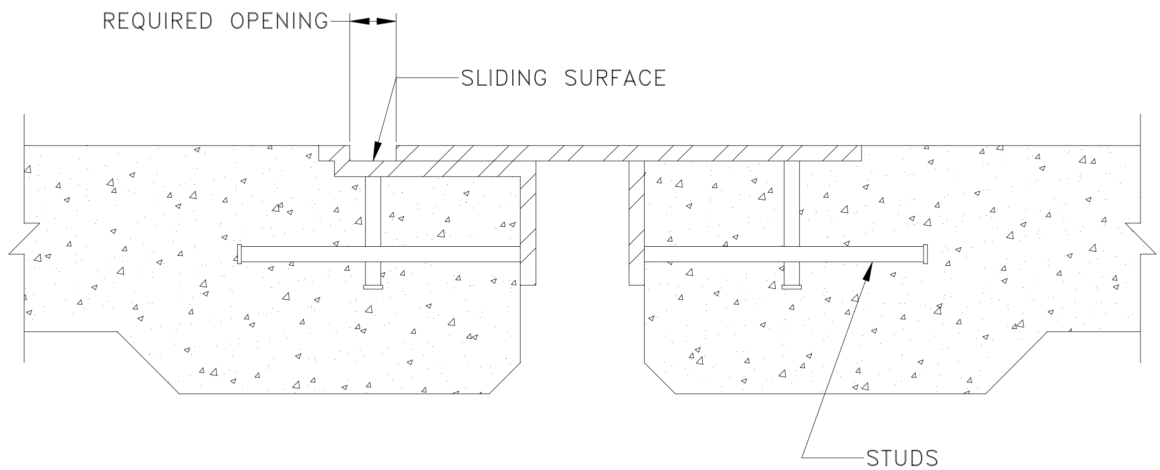
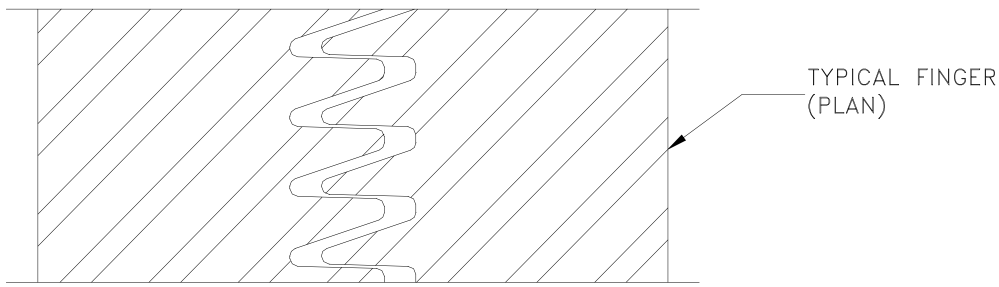


Figure 1-3
Finger Joint



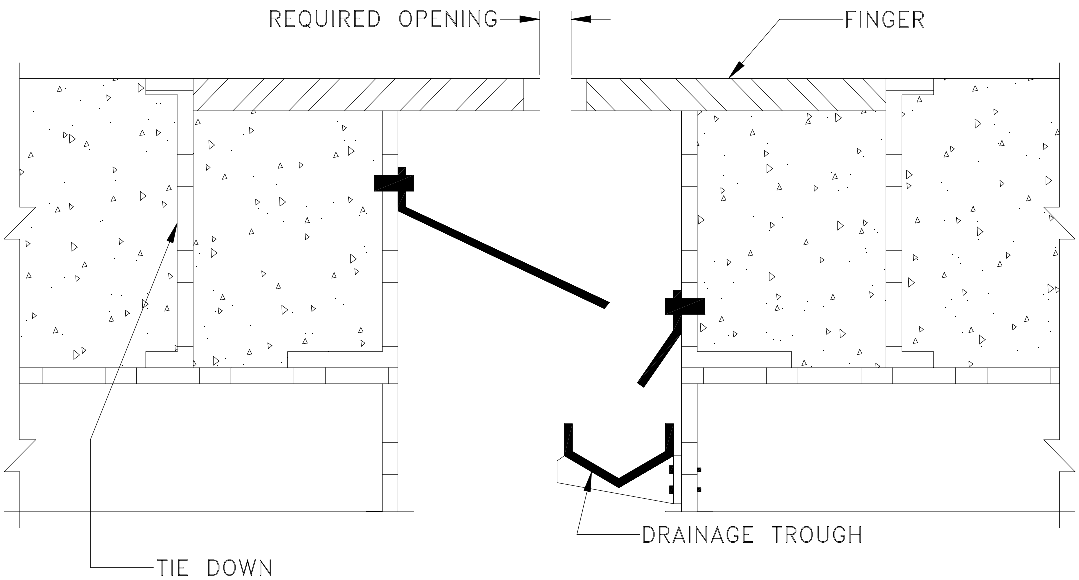


Figure 1-4
Filled Joint

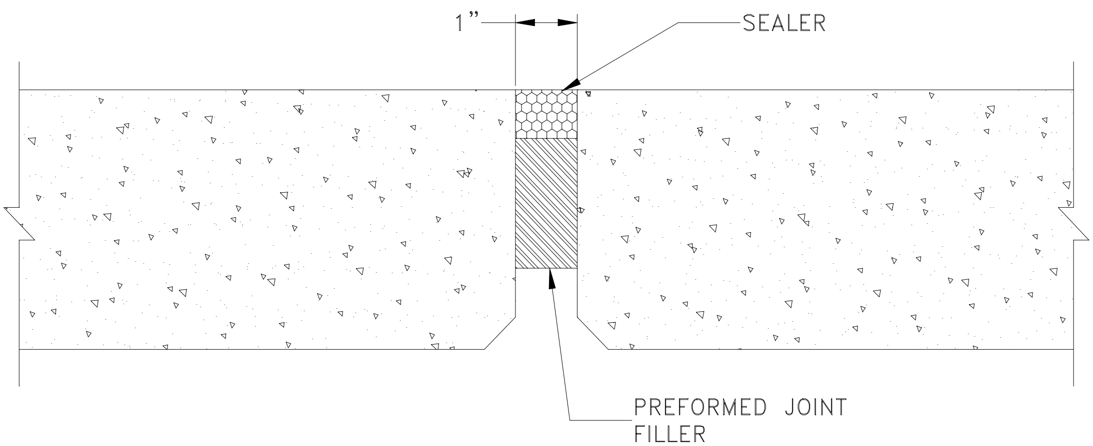


Figure 1-5
Compression Seal

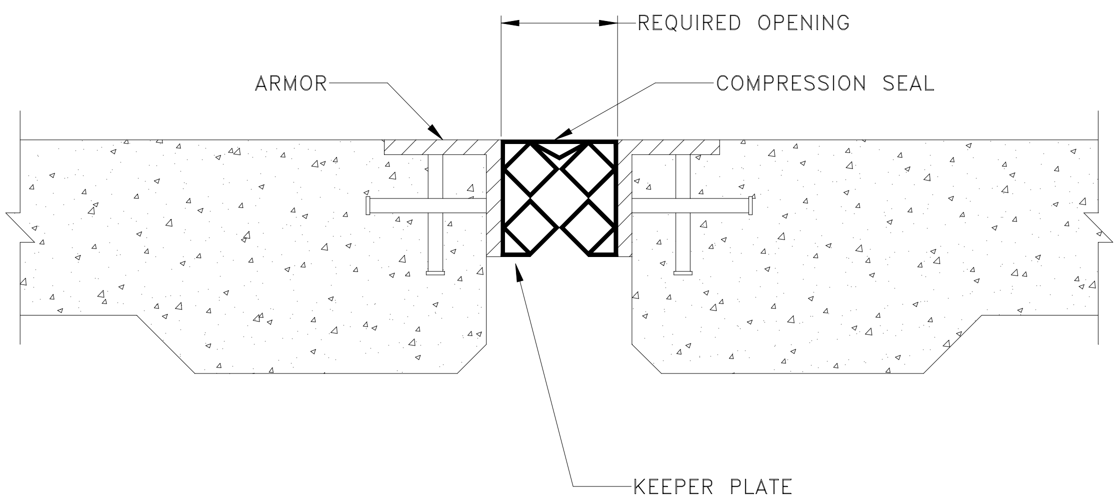


Figure 1-6
Compression Seal Bending Diagram

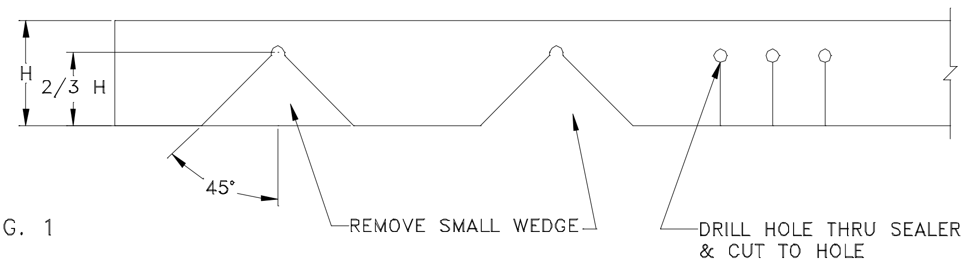


FIG. 1

UP–TURN/DOWN–TURN DETAIL

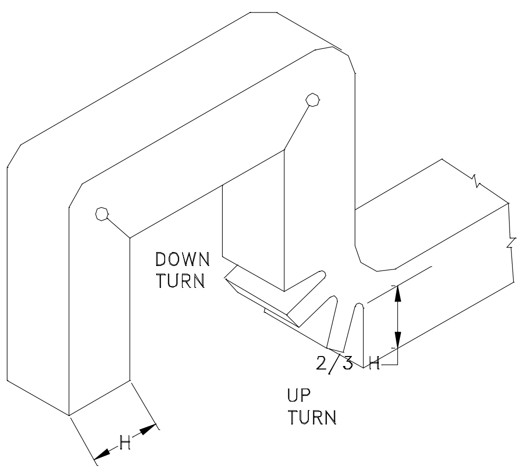
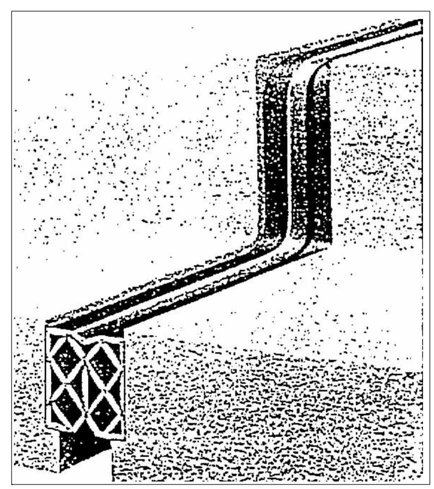


FIG. 2



(FOR CLARITY, SEAL IS
SHOWN UNCOMPRESSED.)
COMPLETE INSTALLATION

Figure 1-7
Membrane Seal

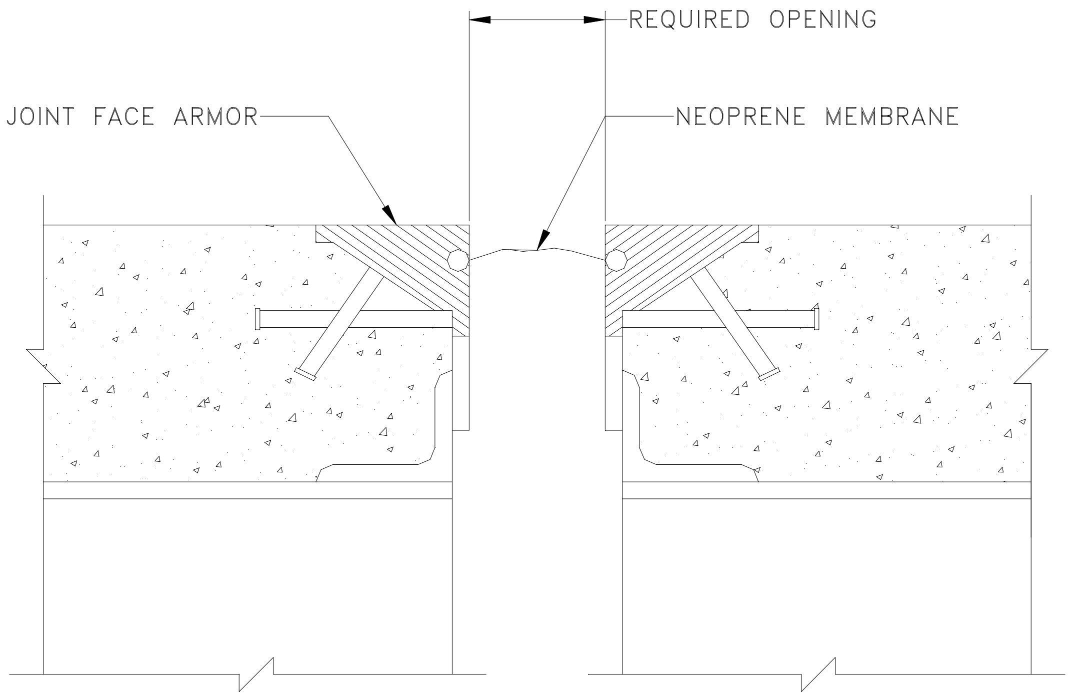


Figure 1-8
Cushion Joint

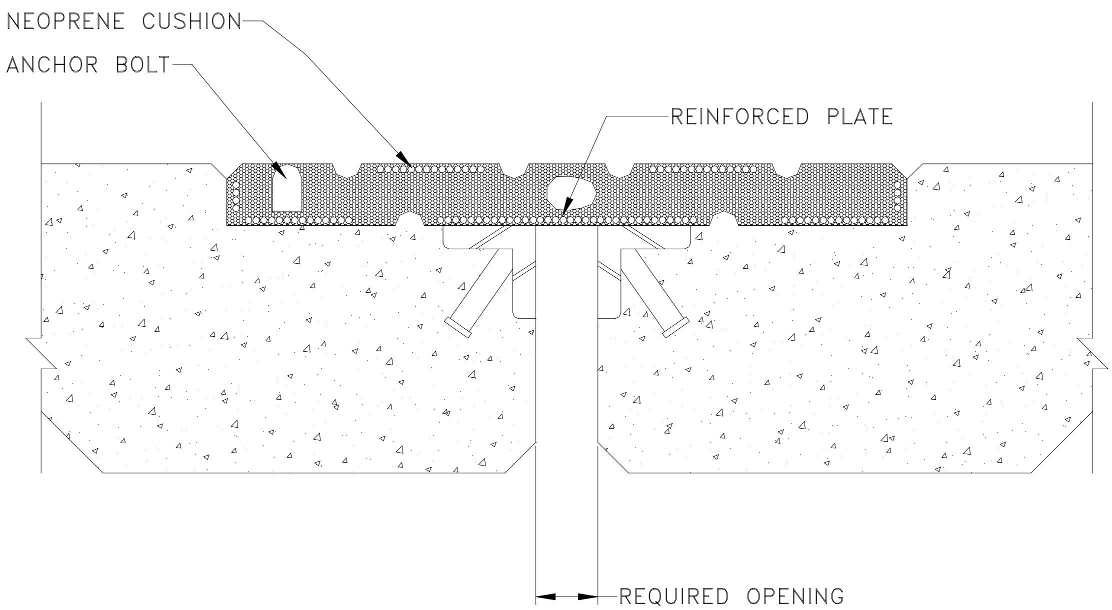


Figure 1-9
Modular Joint Seal

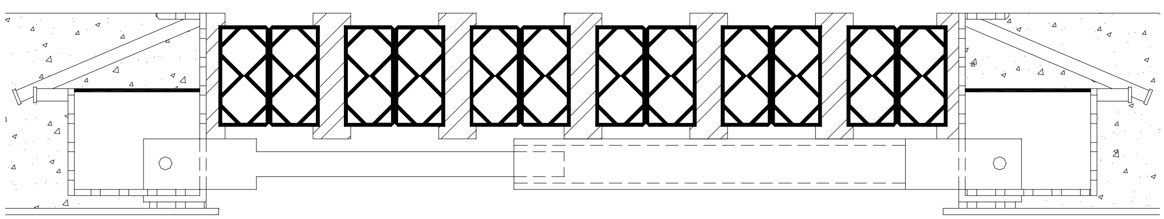
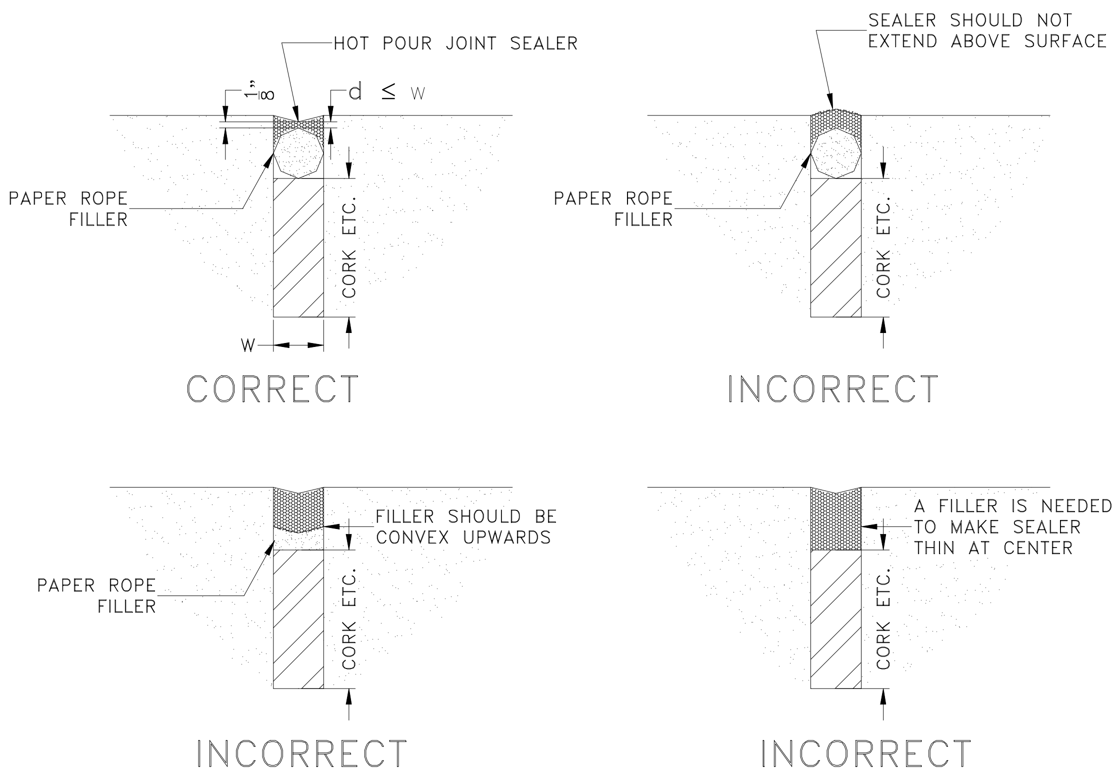


Figure 1-10
Hot Poured Seal Installation



≤ MEANS LESS THAN OR EQUAL

Figure 1-11
Armor Angle Joint Repair

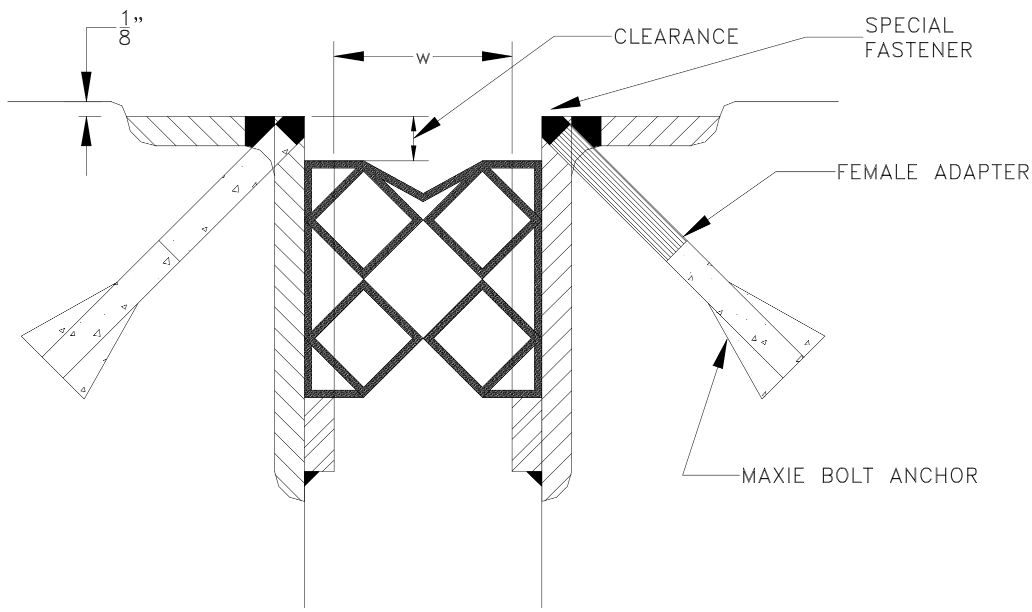
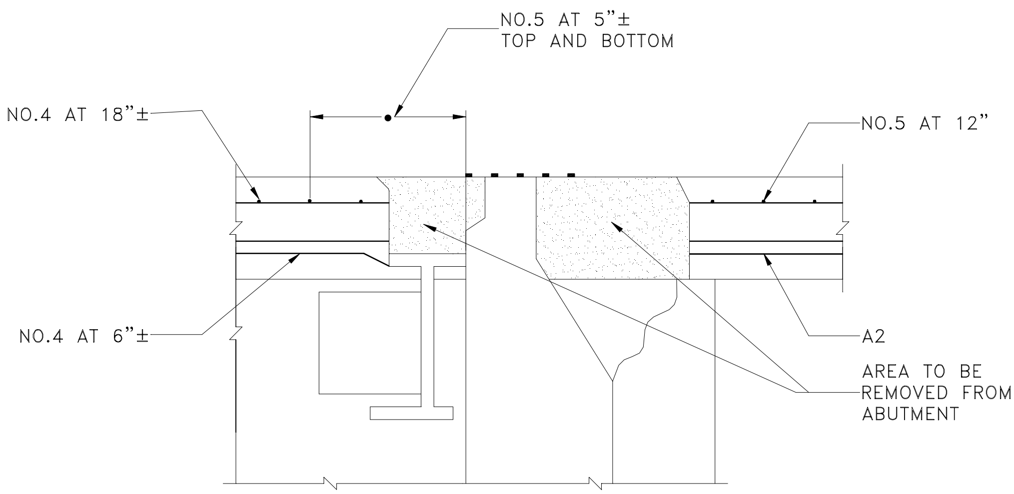
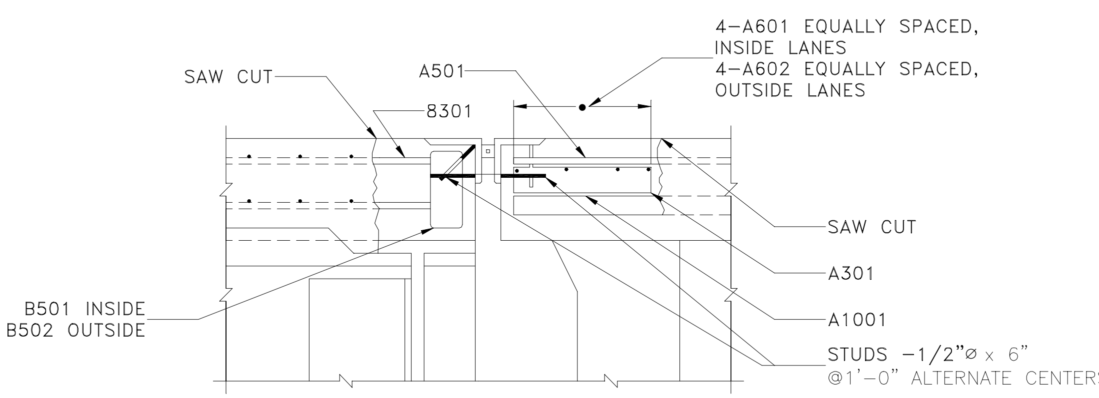


Figure 1-12
Armor Angle Joint Replacement



EXISTING SECTION AT ABUTMENT



DETAIL OF REPAIR ABUTMENT

Figure 1-13
Loose Sliding Plate Joint

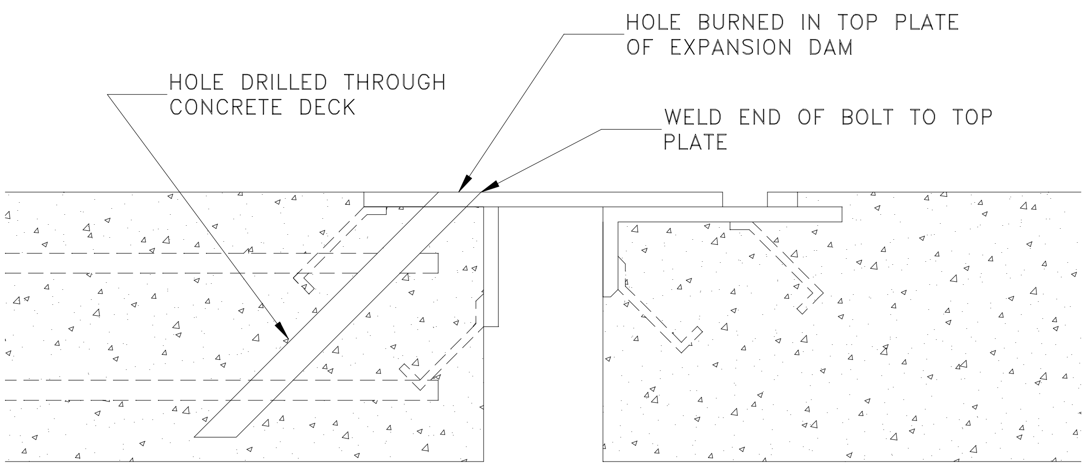
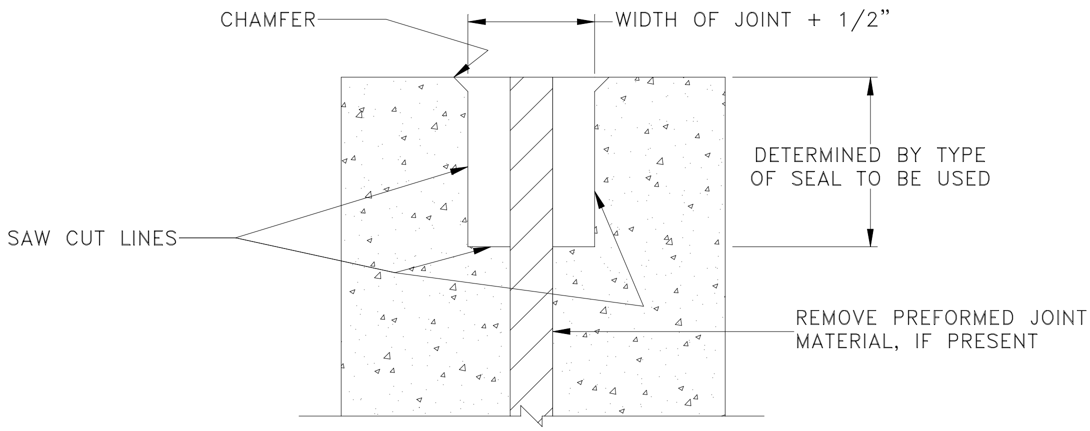


Figure 1-14
Compression Seal Replacement For Deteriorated Poured Joint



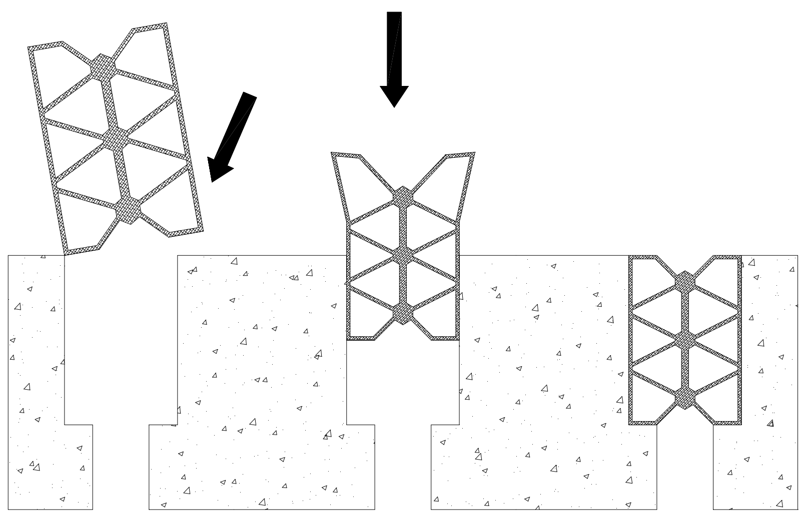


Figure 1-15
Compression Seal With Overlay

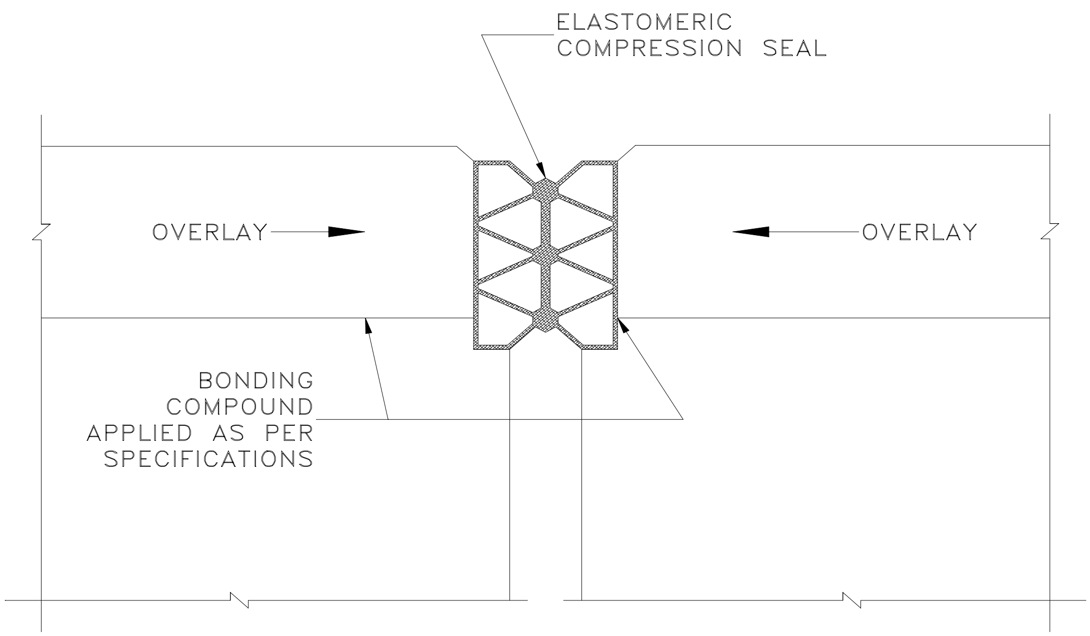
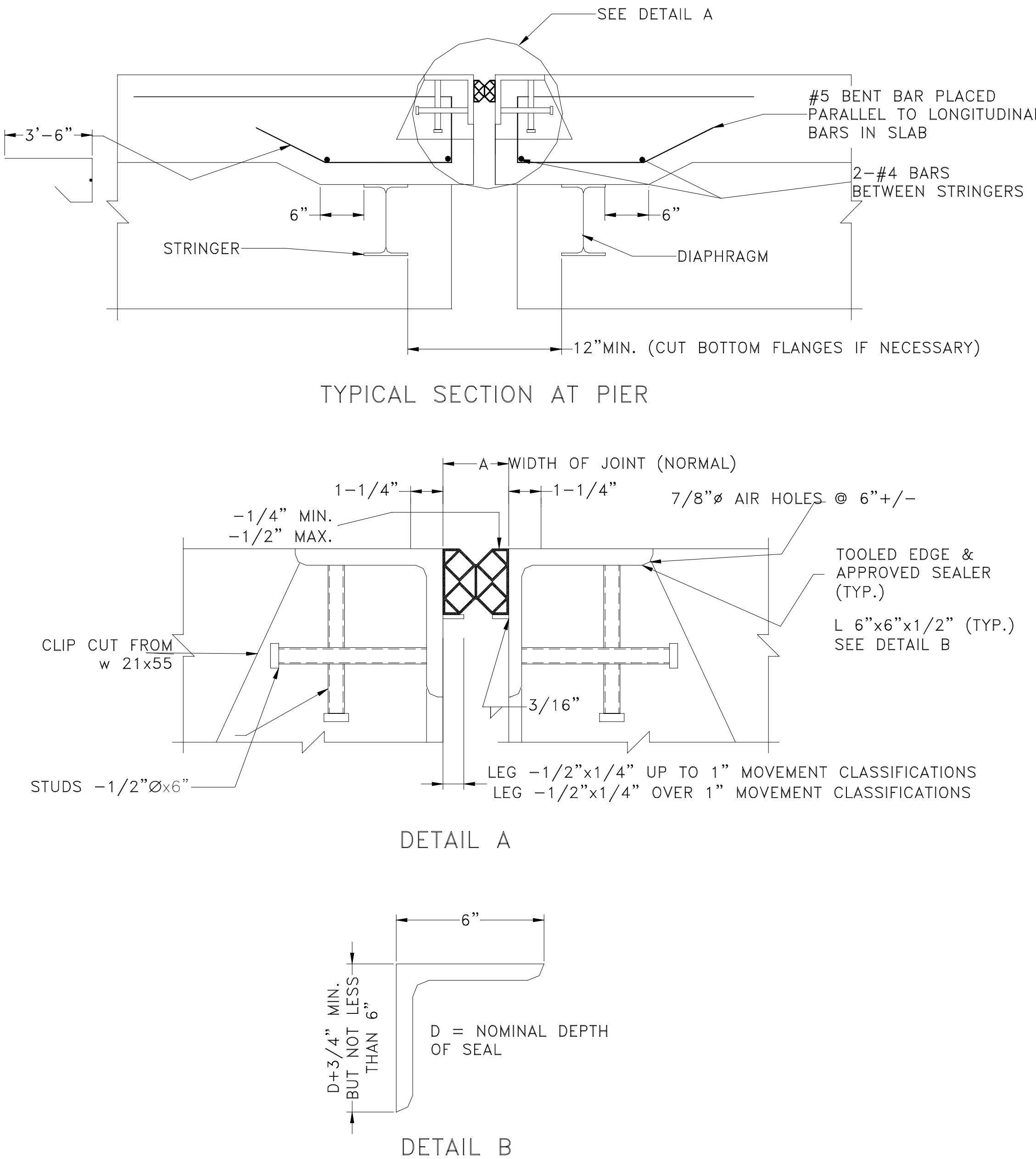


Figure 1-16
Replacing Joint With Compression Seal



CHAPTER 2

DECKS

2.1 BRIDGE DECK CLEANING

2.1.1 Cleaning Operations

Removal of debris by hand sweeping, shovel, high-pressure water/air or mechanical devices.

A. Recommended Method

1. Sweep loose material from sidewalks into bridge deck by hand or mechanical means.
2. Remove large pieces of debris from deck and sidewalk by hand or with front end loader.
3. Sweep and collect material from the deck. Do not deposit material in drainage features or joints.
4. Remove remaining dirt and debris from deck joints and drains.
5. Flush deck, sidewalks, parapets, light and sign standards with high-pressure water/air or mechanical devices as required.

2.2 CONCRETE DECK MAINTENANCE & REPAIR

Refer also to the <u>Bridge Maintenance Training Manual</u>, FHWA-HI-94-034, Chapter XII, *Deck Maintenance Procedures,* Section A, *Deck Maintenance.*

2.2.1 Preventive Maintenance of Concrete Decks

The main objective of preventive maintenance for concrete bridge decks is to control salt and moisture penetration to prevent and arrest corrosion of the reinforcement steel. Several activities may be required to accomplish this objective.

A. Recommended Method

1. Keep the deck clean and provide good surface drainage by keeping the drains open.
2. Monitor the condition by testing for chloride penetration, delamination and active corrosion.

3. Seal or overlay the surface to prevent and reduce salt and moisture penetration.
4. Seal cracks to prevent and reduce corrosion of the reinforcement steel.
5. Remove and replace (patch) deteriorated concrete.

2.2.2 Concrete Deck Sealing

Sealing is accomplished by providing a deck with a barrier to prevent chloride penetration of the deck. All of the sealer materials require penetration as the surface film is quickly worn away by traffic abrasion. There are many types of sealers including silanes, siloxanes, silicone, and polymers such as epoxies and methylmethacrylates. Proper application generally requires dry decks with warm conditions. The surface must be clean prior to the application.

A. Recommended Method

1. Clean the deck by brooming, washing, or air-blasting. Some sealers may rest on the surface of concrete with high film thicknesses. In that case, surface preparation may include sandblasting or shot-blasting to provide bond with the concrete.
2. Make sure conditions are in accordance with the manufacturer's specifications for application of the sealer. The following conditions should be checked:

   a. correct temperature of air and deck;
   b. temperature range of materials as recommended;
   c. wind velocity not to cause drift;
   d. no falling temperatures;
   e. clean deck with no moisture or oil;
   f. any other condition that would prevent a satisfactory job.

3. Mark off or measure areas to be covered in order to ensure the correct rate of application.
4. Prepare sealer as required, remembering some materials will set by chemical reaction so correct proportioning and thorough mixing are vital.
5. Apply sealer as recommended by either:

   a. spray using pump tanks or mechanical spray equipment;
   b. notched or un-notched squeegees;

c. rollers;
d. distributors.

6. For sealers that rest on the surface, follow-up immediately with anti-skid material (usually sand) if required. It is important to get this material in place while it is able to embed itself in the sealer. For sealers that penetrate the surface, sand is not required. However, these sealers usually have a tendency to make the deck slick prior to penetration. Sand should be available if traffic will be on the deck. In case complete deck penetration does not occur, place the sand where there is excess material.
7. Anticipate cure times in the method of operation, both for lane closures and proper curing and or deck absorption.
8. Appropriate precautions should be observed regarding worker safety and preventing materials from escaping the deck area into the environment.

2.2.3 Concrete Deck Patching

The need for deck patching is almost always caused by corrosion of the reinforcement. Deck patching is a temporary repair unless all chloride contaminated concrete is removed before the deck is patched. When only the spalled and delaminated concrete is removed, the corrosion of the reinforcement steel continues and additional spalled areas will appear. For permanent patching, an in-depth deck inspection is required to accurately identify the extent and limits of the contaminated concrete.

Regardless of whether the repair is permanent or temporary, potholes cannot be tolerated when they adversely affect the rideability and safety of the deck. Rough decks also increase the vehicular impact on the bridge, which accelerates the damage and may contribute to structural damage as well. Therefore, when the reinforcement in a concrete deck is not adequately protected from saltwater penetration, deck patching will be necessary.

A. Recommended Method

1. Assess areas for patching using hammers or a chain drag. Delaminated areas will have a distinct hollow sound.
2. Using lumber crayon or spray paint, outline the area to be patched allowing some extra edge areas for undetected delamination, usually in straight lines to facilitate the use of a concrete saw. Corners should be square (no feathered edges). To ensure coverage of the delaminated area, the

line is usually about 6 inches beyond the detected delamination.

3. Usually a concrete saw is used to saw vertically for about 3/4 inch around the perimeter of the hole in order to provide a shoulder for the patch to bear against. Care must be taken not to cut any reinforcing steel in the deck. It is important not to saw past the corner of the patch since this area can become subject to spalling and can present further problems. Better results can be expected if the numbers of individual patches are minimized. If the patches are within 2 feet of each other, they should be combined.
4. Using hand tools and pneumatic hammers weighing 30 pounds or less (15 pounds at reinforcing steel), and at an angle of 45 to 60 degrees to the deck, remove the concrete within the designated area. Periodically sound the concrete to ensure that the area and depth are correct and free of deteriorated concrete. Fracture lines over a reinforcing bar indicate an area that will soon spall and should be removed.
5. The area to be patched (the hole) should be cleaned thoroughly using sandblasting or water blasting to remove any loose concrete, rust, oil, or other contaminants that would prevent a proper bond. Loose fragments still in place may be detected by moistening the surface and looking for their outline as the surface dries.
6. Reinforcing steel is likely to be deteriorated as a result of corrosion. If it has lost over 20 percent of its original cross section, new steel should be added by overlapping, welding, or mechanically connecting with the deteriorated bar.
7. Patching is normally grouped into three categories based on depth:

   a. Type A is above the top layer of reinforcing steel.
   b. Type B is from the deck surface to at least 1 inch below the top mat of rebars.
   c. Type C is full deck depth.

   These depths can only be established with certainty during concrete removal. Verify a Maintenance of Traffic Plan is required for the deck repair. If Type C is suspected, access to the underside of the deck may be needed.

8. Type A patching may require special aggregate size in that the diameter of the rock can not be larger than the depth of the hole. Rebars will not be involved. The danger here is that the patch may be too thin for concrete, or it may be too

thick for epoxy mortar. Epoxy patches in particular, and polymer material patches in general, should be placed and consolidated in layers of limited thickness as recommended by the formulator. The maximum layer thickness may be 3/4 to 1 inch thick. In bridge deck repair, application of more than one layer may not be practical because of concern over restoring traffic quickly.

9. Type B patching will involve rebars and it is important that space be left under the bars to allow fresh concrete to flow beneath them so no voids are left underneath. Type B patching will probably be too thick for epoxy mortar, unless it is applied in layers.
10. Type C patching will involve form work to support the bottom of the patch. This can be simply a piece of plywood wired to the rebars or form work supported with joists. If any Type C patch is expected to exceed a 4 foot by 4 foot area, then a registered engineer should be consulted. This is because the bridge strength may be affected by extensive large-area patching, an errant vehicle may penetrate the open hole, the deck may be at the end of its useful life, or extensive Type C patching may not be economical.
11. The surface of the existing concrete adjacent to the patch should be damp but free of standing water when fresh concrete is placed in the hole. A straight board can be used to level the patch. With a small patch, a hand float can be used to finish the surface. Patches should not deviate more than 1/8 inch in height from the surrounding concrete.
12. If the restoration of traffic before rush hours, either night or day, is a requirement, the use of quick set, hydraulic patch materials is suggested. Non-shrink materials should be used. Several pre-proportioned quick-set hydraulic materials are available in sacks. They are mixed with water at the site using a small portable mixer. Minimum compressive strength is generally 2,000 psi in two hours. In order to achieve fast curing, proportioning and mixing instructions for the material that is used must be followed exactly. Failure to do so could result in delayed opening to traffic and a possible weak and porous patch.
13. If the concrete is mixed from scratch, the mix should be designed by a materials engineer and furnished to maintenance forces with a strength versus time curve. The deeper the patch, the higher the strength requirements for restoration of traffic. As a guide, Type A would need 1,000 psi, Type B needs 2,400 psi, and Type C needs 3,700 psi before opening to traffic. It should be emphasized that

before a large area is patched, the advice of a registered engineer should be obtained as excessive concrete removal could lower the bridge capacity.

14. Wet curing of the patch is preferable, except for polymer patches. This can be done with dampened burlap kept on the patch surface until ready to open to traffic. If the material does not give off a lot of heat, a membrane cure is satisfactory. With quick-set hydraulic material, in two hours the concrete set can be adequate for traffic use.

2.2.4 Other Deck Patching

A. Epoxy Deck Patching

A brief explanation of epoxy patching procedures is given; however, epoxy is not a widely used patching material. The maximum depth of epoxy patching may be 3/4 to 1 inch because of its high shrinkage factor. The hole should be reasonably square. Epoxy patching, if done correctly, does not require a sawed hole.

It is essential that the bottom and sides of the hole be free of any moisture, dust or dirt that will prevent good bonding. A good way to ensure this is to air-blast the hole. The epoxy used is a two component product and it should be mixed with a low speed drill, 400 to 600 rpm, until the blend is uniform in color. This will usually take about three minutes of mixing. The entire surface of the hole, including the steel (Type B patching) should be painted with this blended material. Puddles should not be left in the bottom of the hole nor any areas left dry. If there are puddles, the excess material will bleed out onto the surface resulting in a weakened portion of the patch.

Experience indicates that approximately 1 part epoxy to 4 to 7 parts of well-graded, dry sand is the best mix. The epoxy should never be added to the sand.

An electric mixer can be used for mixing small quantities; for larger quantities, a standard mortar mixer can be used. It is essential that the mixed material be placed in the hole as soon as possible. The material should be worked to eliminate any voids and to get compaction. The patch should be struck off with a hand float or a straight edge. Speed is essential since the material sets up quickly, especially in warm weather. In temperatures below 65 degrees Fahrenheit, the strength gain may be very slow and cause a problem.

B. Asphaltic Concrete Patching

Asphaltic (bituminous) concrete is a porous pavement material that is not capable of waterproofing the bridge deck concrete. Moisture (with salt) penetrates the asphalt and is trapped on the top of the deck. Also, the saturated asphalt concrete will act similar to a sponge and will prevent the concrete surface from drying. The use of asphalt concrete patch will cause or accelerate deck deterioration unless a waterproof membrane is placed between the patching material and the deck. The only time that the use of asphalt concrete is permissible on a deck without waterproofing is as a temporary patch on a deck where the deterioration is so advanced that replacement is the most cost-effective permanent solution to the problem.

C. Emergency Full-Depth Patching

There are several emergency methods to patch a deck when the hole is full-depth. Caution must be used in evaluating these situations as a structural weakness in the bridge may be overlooked in trying to satisfy traffic demands. Ordinary plywood with joists may be suspended by wire from the reinforcing steel and a small full-depth hole filled with quick-set hydraulic mix. See Figure 2-1. Steel plates are also an option. The plates must be bolted at the corners to keep them from moving. A registered professional engineer shall approve all repair methods.

2.2.5 Crack Sealing

Crack sealing is an important part of concrete deck maintenance. Concrete cracks that reach the reinforcing steel and have widths larger than 0.007 inch, the thickness of two sheets of paper, will allow moisture and chlorides to penetrate and cause corrosion.

A. Crack Causes

Determine the type of crack and its cause before attempting to seal the cracks, since this may affect the type of repair. The most common causes of concrete deck cracks are listed below:

1. Transverse cracks are often caused by thermal and/or drying shrinkage of the concrete. Material defects such as use of aggregate that cause shrinkage, improper quantities such as too much water in the concrete mix, or improper curing of the concrete deck during construction can induce shrinkage cracking.

2. Transverse cracks may also be caused by flexure of the deck or lack of cover on the reinforcement.
3. Longitudinal cracks are common over the joints between prestresses, precast adjacent concrete box beams or sonovoid slab units. The cracks are caused by non-uniform bending action of the beams under traffic. Longitudinal cracks also occur over the longitudinal beams of other bridge types when the beam spacing is large and the deck bends over the beams.
4. Random, map or alligator cracking results at locations where excessive shrinkage occurs in fresh concrete due to rapid evaporation, or they result due to factors such as aggregate-cement reaction.
5. Foundation settlement can cause a twisting force on a concrete deck that generally results in a diagonal cracking pattern.
6. Thermal expansion caused by a high temperature combined with debris filled expansion joints can cause deck cracking, or spalling, near expansion joints.

B. Small Cracks - Liquid Sealers

Small cracks can be filled by some of the liquid sealers on the market to waterproof decks. These products should be considered for use over the entire deck when cracks are numerous.

C. Dormant Cracks - Pressure Injection

A crack sealing material (such as epoxy or polyurethane) can be pressure injected into larger dormant cracks. This is done by drilling holes (ports) along the crack and injecting the sealant through those “entry ports”. The maximum port spacing should not exceed the depth of the crack. Prior to injection, the surface of the crack should be sealed to keep the injection material from leaking out before it has gelled. The sealing of the surface is usually done by brushing an epoxy along the surface of the crack and allowing it to harden. If the injection pressure is extremely high, the sealing of the crack surface may be done by V-grooving the crack and filling the groove with epoxy mortar. Since some deck cracks are likely full-depth, they must also be closed from below, before they are pressure injected from top. This may be done be brushing an epoxy along the crack from below, since the injection pressure at the bottom of the deck will usually be low due to the depth of the crack. Note that where a stay-in-place form is used in the deck construction, the form is an adequate seal.

Crack injection is more successful if cracks are clean before injection. Methods to clean cracks include:

1. vacuuming;
2. air-blasting;
3. water-blasting;
4. chemical washing and flushing.

If the crack is too widely rutted with spalled edges, it may be necessary to saw-cut the crack edges before sealing and injection. This is to avoid the crack-sealing material from being feather-edged and becoming a long-term spalling problem under traffic.

D. Working Cracks - Joint Sealer

If the crack is open and shows evidence of movement, if it has been sealed before and has failed again, or if there is evidence of recent re-cracking such as dust or surface re-grout failure, it is a “working” crack and should be sealed with a flexible crack sealer. See Figure 2-2. The sealer material should be designed for the anticipated movement. Usually this involves cutting a slot with sufficient width over the crack to hold the sealer. The sealer may be a hot- or cold-poured flexible material. Important things to remember in crack sealing are:

1. the cause of the crack should be addressed as part of the solution;
2. before sealing, the crack surface must be clean and dry;
3. the depth must be less than or equal to the width of the seal.

2.2.6 Overlays

Overlays may be applied as preventative maintenance or as part of deck repairs. When an overlay is applied as part of a repair to an existing deck, it is very important to make sure that deteriorated and contaminated concrete is removed. When rigid overlays are applied, it is common practice to remove 1/2 inch from the top of the deck leaving a roughened surface. The roughened surface will provide bond and integrity between the overlay and the deck.

The extra weight of the overlay should be a consideration when an overlay is used. This additional deadload reduces the structure's capacity to carry liveload. The reduced capacity may be unacceptable unless a comparable amount of the old concrete is removed. Depending on the thickness of the new overlay, it may be necessary to remove more of the existing concrete, say 1 1/2 inches, to minimize the deadload. The depth of steel should be checked to ensure it will not be damaged or exposed when the concrete is removed.

The concrete removal areas are patched with regular deck concrete leaving a roughened surface and the appropriate space on top to apply the overlay. It is also possible to fill the concrete removal area with the overlay concrete at the same time the deck is overlaid. This is called "monolithic" repair. If monolithic repair is performed, it is important that concrete is vibrated internally in the removal areas.

Most overlay systems are designed to be less permeable to moisture and salts than normal deck concrete. The most popular deck overlays used are:

A. Cementatious Overlays

Cementatious overlays include concrete, latex-modified concrete, silica fume concrete and fiber-reinforced concrete. They are normally approximately 1 to 2 inches thick. The mix has small aggregates, 1/2 inch maximum, and a low water/cement ratio to achieve a dense and impermeable mix. Cementatious overlays are transported to the site, placed on the deck, screeded and finished the same as a conventional bridge deck placement. Before they are placed, the existing deck is roughened and a cement grout is applied as a bonding agent. The same type of screeding and finishing equipment is used in placing a concrete overlay as in placing the deck.

Since the thickness of cementatious overlays is relatively low, curing is very important. The following special precautions should be taken:

The existing deck should be pre-wetted so that it will not draw moisture from the mix. The surface should preferably be drying at the time of concrete placement.

It is best not to place the overlay in very hot or windy conditions, since those conditions can cause cracking due to rapid evaporation of bleed water from the concrete surface.

The finishing should be performed expeditiously and the curing should begin as soon as possible after the finishing is complete. Delayed curing can cause cracking and increased permeability.

Cementatious overlays are modified in various ways to reduce the permeability and, thereby, improve the resistance to corrosion damage from salt. The method used to achieve the lower permeability is as follows:

1. Concrete

   Concrete overlays (may be called low-slump concrete or the "Iowa method") have a low water/cement ratio to achieve a dense mix. Workability may be a problem because of the low water/cement ratio.

2. Latex Modified Concrete

   A latex additive is included in the concrete mix to improve the workability of the low water/cement concrete. The latex additive also makes the concrete self healing with improved bonding and is less permeable.

3. Silica Fume Concrete

   Silica fume is a more recent additive used to achieve a low permeability concrete. It produces a stiff and sticky mix that may be more difficult to finish. Usually, a super-plasticizer admixture is used to improve the workability.

4. Fiber-Reinforced Concrete

   Either steel or polyester fibers are added to the overlay mix to improve the tensile strength of the concrete. The fibers are intended to improve the resistance of the overlay to certain types of cracking. The fibers present special problems in finishing and texturing the surface. While the reduction of cracks should improve the resistance to corrosion, the fiber-reinforced overlay is not less permeable unless other changes are made to the mix.

B. Bituminous Concrete with Waterproof Membrane

Bituminous (asphaltic) concrete overlays have probably been used longer than any other type. It was originally used without a waterproofing membrane to improve the riding surface rather than protect the deck. As mentioned previously, the bituminous concrete is porous and absorbs moisture. Chlorides and moisture penetrate this type of overlay and are trapped against the deck, accelerating the deck deterioration. In the past, layers of bituminous concrete have been placed on bridge decks by road paving crews, adding weight to the bridge thereby reducing its capacity to carry loads.

Bituminous concrete is used with a waterproof membrane to prevent intrusion of moisture and salt into the deck. The role of the bituminous concrete is to protect the membrane against the traffic. Two types of membranes are used. Those that are:

1. Applied in-place

   Applied in-place membranes are usually squeegeed on the surface.

2. Preformed

   Preformed membranes are delivered from the manufacturer in rolls and are directly applied on the deck after it is primed. Sometimes sealants or an epoxy resin system are used on the deck instead of a membrane. Much care must be exercised in placing the bituminous pavement over the waterproofing material not to damage the waterproofing qualities.

Bituminous concrete/waterproofing membrane system was the popular system before latex-modified concrete became available. Bituminous concrete is usually less durable than a rigid concrete overlay. Thus, when exposed to heavy traffic the overlay will deteriorate rather rapidly. This will require removal and replacement of the overlay itself, regardless of the deck condition.

A chip seal can also be applied. In this method, liquid bituminous material is followed by an application of an aggregate.

C. Polymer Overlays

Essentially the polymer overlay consists of a polymer applied to the deck surface with sand, or another similar fine granular material, broadcast on top to improve skid resistance of the polymer. No other wearing surface is used. Up to three layers may be applied in this fashion to provide the required thickness. Epoxy overlays have been used for quite some time with varying success.

Past problems include brittleness of the epoxy over time, porosity of the overlay caused by penetration of the sand into the polymer material, loss of the sand in the overlay due to traffic wear, and de-bonding of the epoxy, in sheets, under heavy traffic. The overlay de-bonding is the result of pounding of the traffic or fluctuation of the temperature. Polymer concrete tends to expand and contract much more than deck concrete when the ambient temperature fluctuates. This incompatibility causes the de-bonding at the interface with the deck. However, sometimes the presence of a very strong bond between the polymer and deck causes the concrete to delaminate just below the thin overlay. Improvements have been made in polymers to minimize such problems.

2.2.7 Concrete Deck Replacement

Deck replacement is usually considered a major event that may trigger consideration of certain capacity and safety improvements. Most bridge maintenance crews do not attempt concrete deck replacement because of the manpower, material, and equipment requirements.

2.3 STEEL GRID DECK MAINTENANCE & REPAIR

Refer also to the Bridge Maintenance Training Manual, FHWA-HI-94-034, Chapter XII, *Deck Maintenance Procedures,* Section A, *Deck Maintenance.*

Steel grid decks are common on movable lift spans where the weight of the deck is a major consideration.

2.3.1 Common Maintenance Concerns

A. Welds and Rivets

The welds or rivets that join the grids and hold them down may break, and should be repaired or replaced since this presents a potential hazard. It may be necessary to reinforce or replace damaged grid plates. When several plates have been damaged or dislodged, it is best to cut out and replace the portion of the deck.

B. Open Drainage

The open grid does not protect the portions of the bridge under the deck from exposure to roadway drainage.

C. Traction

Steel grid decks are noisy and tend to become slippery when wet. A scabbler device can be used to roughen the surface of the steel grid deck.

2.3.2 Replacing Damaged Grid Plates

A. Recommended Method

1. Locate and mark defective decking.
2. Cut decking along centerline of beams that encompass the entire affected area.
3. Measure cut section and cut replacement decking to required size.
4. Cut welds that hold decking in place.
5. Remove cut section of decking.
6. Grind off weld remnants from tops of support beams.
7. Set new decking in place. Support beams should run parallel to the centerline of the roadway, and the bearing bars should be perpendicular to the roadway centerline.
8. Weld new decking in place using 3/16 or 5/32 inch welding rods, forming a 1/4 to 1/2 inch fillet weld, 1 1/2 to 2 inches long, on each side of the deck bearing bar. Stagger the fillet welds.
9. Check for loose decking on other sections of the bridge. Loose decking should be rewelded to the support beams. Do not reweld over a broken weld. Use clear areas for the new welds, otherwise, grind off the broken weld and reweld in the same location.
10. Repair loose grating with 3/16 and 5/32 inch vertical welds between cross bars and supplementary bars. Loose bars can be found by tapping with a hammer or listening when traffic passes.
11. Clean and paint the repaired section as necessary.
12. All welding should be done by a welder certified for the type and position required.

2.4 TIMBER DECK MAINTENANCE & REPAIR

Refer also to the <u>Bridge Maintenance Training Manual</u>, FHWA-HI-94-034, Chapter XII, *Deck Maintenance Procedures,* Section A, *Deck Maintenance.*

Usually, timber decks are the easiest type to repair. Broken, worn, or decayed planks can generally be replaced with little difficulty. Care must be taken to nail planks so that they are securely fastened. Plank or laminated timber decks may be fastened to steel I-beams by using metal fasteners. See Figure 2-3. When a bituminous wearing surface is used to improve traction and ride quality, it should be carefully maintained.

2.4.1 Timber Deck Replacement on Steel Beams

A. Recommended Method

1. Remove and store deck mounted curbs, parapets, wheel guards and railing.
2. Remove existing deteriorated decking that can be repaired or replaced in the same day.
3. Clean and paint top flanges of beams.
4. Place deck planks on the beams, perpendicular to the beams. Planks should be placed with the edge against the beam flange. Planks must be of sufficient length to be supported by a minimum of three beams. Avoid joints if possible. If joints are necessary they should be staggered.
5. Spike each plank in place, with spikes spaced 12 inches apart and alternating between 2 inches from the top to 2 inches from the bottom.
6. Place anchor plates on each beam spaced 1 foot apart on alternating flange edges.
7. Apply wood preservative to the ends of any plank that is field cut.
8. Re-install the deck-mounted appurtenances after the wearing surface is applied.

2.5 APPROACH SLAB MAINTENANCE & REPAIR

Refer also to the Bridge Maintenance Training Manual, FHWA-HI-94-034, Chapter XV, *Miscellaneous Maintenance Procedures*, Section A, *Approaches.*

The settlement of the bridge approach pavement is a common problem. The pavement settlement results in poor ride quality on the approach and may pose a safety problem in severe cases of uneven settlement. In addition, when heavy trucks travel over rough sections of pavement, impact loads may be created that can damage the structure. The settlement usually results in cracked pavement that can become severe if the settlement is allowed to continue. Pavement settlements can be a recurring problem. It is often necessary to periodically repeat the repair procedure.

2.5.1 Causes of Settlement

A. Common Settlement Causes

1. Poorly compacted fill material adjacent to the abutment that continues to consolidate over time.

2. Voids behind the abutment resulting from scour caused by the waterway, or erosion from surface drainage. Spill through or column abutments (end bents) are particularly prone to this problem. A small rock drill can be used to locate and determine the size of voids under the pavement.
3. A slight tilting of the abutment that creates a small void near the pavement seat. This situation may be further aggravated by the pressure of the pavement pushing against the abutment, producing additional movement.

If settlement is occurring, it is very important that the cause of the problem be determined. If scour is creating a void, the condition could become unsafe; additional layers of blacktop will only temporarily hide the problem and contribute to the unsafe condition because of the increased deadload over the void.

2.5.2 Repair Methods

There are various methods of repairing the effects of bridge approach pavement settlement, including:

A. Wedge Overlay

A bituminous wedge overlay is applied to the approach pavement to compensate for the settlement. This is a commonly used method for temporary repair of slight settlement. It is acceptable if the problem is embankment consolidation but should not be used if a void is present.

B. Overlay

If the approach pavement is concrete, a polymer mortar overlay can be applied and feathered as necessary on the approach pavement. This may be done in conjunction with a bridge deck overlay project.

C. Replacement

Complete removal of the pavement or approach slab. This is followed by filling and compacting any voids in the approach fill with suitable material before replacing the pavement or adding a new slab.

D. Mudjacking

Mudjacking to fill the voids and lift the pavement up to its original grade is a common repair. Mudjacking sometimes cracks the pavement, which, combined with the mudjacking holes, creates the need for a bituminous overlay to achieve a smooth ride. Following is a more detailed description of the mudjacking repair.

2.5.3 Mudjacking

Mudjacking is a method of raising settled portions of pavement by filling any voids and lifting the pavement by pushing it from below with mud. The procedure consists of drilling holes in the pavement and pressure pumping a slurry of fine soil materials and a hardening agent into the holes, causing the pavement to rise as the slurry fills any voids and flows between the pavement and the fill. See Figure 2-4.

A. Mudjacking Materials

There are many materials that can be pumped. Some of the most common materials are fly-ash, agricultural lime, pond sand, polyurethane, or combinations of these materials. The chosen material should be inexpensive, readily available, and pumpable under pressure without having the carrier water separate from the material. Coarser materials or sand allow this to happen and can cause many problems. Usually when this separation occurs, it is easily corrected by adding a lubricating material to the mix. Cement should be added to the base material. The proportion of cement can vary from 1 to 20 percent depending on the application or the base material being used. The following mixes have proven satisfactory for mudjacking operations:

1. Mix No. 1

   a. 6 parts sand
   b. 2 parts commercial (hydrated) lime
   c. 1 part Portland Cement

2. Mix No. 2

   a. 4 parts sand
   b. 8 parts sugarbeet lime (or 12 parts marl)
   c. 1 part Portland Cement
   d. Cut-back asphalt RC-1, or asphalt emulsion AE-2, or AE-1M at a rate of 1.5 gallons per cubic yard of slurry

3. Mix No. 3

   a. 8-12 parts sand
   b. 4 parts commercial (hydrated) lime
   c. 1 part Portland Cement

d. Cut-back asphalt RC-1, or asphalt emulsion AE-2, or AE-1M at a rate of 1.5 gallons per cubic yard of slurry

The fine sand used may be any type having well-rounded particles. Sufficient water must be added to each of the above mixes to make the slurry workable. Mix No. 2 may be used without the asphalt materials.

B. Mudjacking Procedure

Holes are drilled through the pavement. The diameter of the hole should fit the nozzle on the mudpump. Spacing of the holes depends on the condition of the concrete pavement and the amount of lifting to be accomplished. A typical pattern consists of two rows of holes, each 3 feet from the edge of a 12-foot traffic lane with the holes 6 feet apart along the lane and equally staggered from the holes in the other row. When adjacent lanes are drilled, the holes are staggered from those in the nearest row of the other lane.

The holes should be flushed with water under pressure to create a space for the slurry to start lifting the slab. All except two holes are sealed with wooden plugs or with wooden stakes. The slurry is pumped into the void through one hole until it is visible in the second hole. One of the two open holes is then plugged. The mud is then pumped into a third hole that has been opened. The operation is continued until the slurry has been pumped into each hole and the entire area is raised to the desired level. Care should be taken to guard against overcharging at any location since this may cause additional cracking. When pumping is completed, all drill holes should be refilled with rapid-set cement concrete.

If slurry should blow out on the shoulder, an old grader blade can be wedged along and below the pavement edge. Shoulder material can then be added and compacted to seal off the blow-out. A wide plank, with the dual wheels of the mudjacking equipment placed upon it, is also effective in keeping the shoulder material from blowing out.

Where settled pavement areas to be raised are adjacent to structures, extreme caution should be exercised to prevent the concrete pavement approach slab from rising above the bridge deck. The following two methods have proven effective in preventing over-raising the slab:

1. L-Pin Method

Drill 7/8 inch holes diagonally through the approach slab and into the bridge deck slab. Insert 3/4 inch "L" shaped pins into the holes to pin down the approach slab and prevent over-raising of the bridge deck joint. Usually only two or three pins are needed on a 24-foot pavement. After raising the approach slab, the "L" shaped pins should be removed and the holes filled with mortar. Park the mudjacking equipment or a loaded truck on the approach slab adjacent to the bridge deck joint.

2. Low Slurry Mudjacking

Mudjacking is also used to fill voids under the approach pavement where settlement has not taken place. The procedures followed are basically the same except that the slurry should be held to a minimum because lifting of the slab is not required and the probability of blow out is reduced.

2.5.4 Installing Relief Joints in Approach Pavement

Relief joints are installed to prevent or stop expansion pressure on abutments that results from expansion of concrete roadways. Considerable damage to bridges has been caused by pressure from encroaching pavements. Damage has been caused to abutment backwalls, parapets, rail posts, deck joints, and bearings. Relief joints should be made in the approach pavement as soon as it is apparent that pavement progression is occurring. In winter when pavement contracts, the cracks and joints fill with debris and in the summer when the pavement expands, there is no space for it to expand into; therefore, the concrete cracks.

Relief joints should be located at cracks or joints in the existing pavement. To construct relief joints, a section of the concrete pavement is removed across the width of the roadway. The sides should be saw-cut. The opening is normally 12 inches wide and filled with bituminous material. See Figure 2-5.

Narrower relief joints, say 4 inches, can be filled with bridge deck joint filler/sealers. See Figure 2-6. The system must be checked and additional joints constructed as the pavement continues to grow.

2.6 BRIDGE DRAINAGE SYSTEM CLEANING & REPAIR

Refer also to the <u>Bridge Maintenance Training Manual</u>, FHWA-HI-94-034, Chapter XII, *Deck Maintenance Procedures,* Section D, *Cleaning Deck Drains and Installation of Pipe Drains.*

Correctly operating and well maintained deck drain systems prevent traffic hazards and deterioration of the deck and other structural members.

2.6.1 Cleaning Methods

A. Recommended Methods

1. Remove debris from grating and lift grating from scupper.
2. Remove debris and sediment from scupper box and pipe.
3. Flush pipe and down spouting with water. The pressure of the water should be controlled to avoid damage to joints and anchors.
4. If debris has accumulated in down spouting, remove clean-out plugs as necessary and dislodge with water, snakes, or "roto-rooter" type devices.
5. Replace grating and clean-out plugs.

2.6.2 Drain and Drainpipe Installation

Frequently it is necessary to install bridge drains, particularly drainpipes, after the bridge construction has been completed. The following things should be considered when planning to install a bridge drain.

A. Recommended Method

1. Drain boxes or inlet areas should be as large as possible.
2. Drain covers should be designed for easy removal, yet strong enough to support traffic. Special openings may be required in locations where bicycles are ridden. Lightweight covers require hold-down clips.
3. A wire clean-out basket is preferred for catching debris rather than a catch basin type inlet box. The minimum downspout piping diameter should be 8 inches.
4. The downspout should have a minimum slope of 2 percent, preferably 8 percent. Bends should have a minimum radius of 18 inches, and 90 degree elbows are not recommended.
5. Clean out plugs and elbows should be easily accessible. When connecting the pipe downspout to the bridge, it should be at a location that will not harm the strength of the structure. A bridge engineer should be consulted when making connections to steel bridges to avoid creating fatigue prone details or damaging fracture critical members.
6. Drain outlets should be placed so that they do not cause harmful erosion. When connection to a sewer system is required, it should be remembered that volatile liquids of an explosive nature can enter the system from a roadway spill on the bridge.

7. Certain precautions should be considered, such as a ponding area before the entrance to an enclosed sewer system.

2.6.3 PVC Deck Drain Installation

The simplest type drain and the easiest to install is a straight PVC pipe through the deck. See Figure 2-7. Disadvantages of these drains are that considerable maintenance is required due to the small opening, and if the pipe is not long enough and placed properly, the spill out can cause damage to the structure.

A. Recommended Method

1. Drill holes through the deck and remove sufficient concrete to set a grate of No. 6 reinforcing bar.
2. Set drain pipe and grate bar with epoxy or rapid-set concrete patching material.
3. Plug any old existing drain holes with epoxy or rapid-set concrete patching material.
4. Place riprap or splash block as required under drains.

2.6.4 Drain Extensions

Many structures that were constructed in the 1950's and 1960's were built with short deck drains at the gutter line that barely go through the deck. Most of these drains are located close to the fascia beam (either on the inside or outside of these beams).

Drain extensions can be installed to these short drains to carry water below the lowest members of the support system. In Figure 2-8, a box beam 6 inches x 8 inches (typical, but sized to fit) is cut and welded in place. The weld is ground smooth and the extension is painted. Metal straps and bolts may be used instead of the weld. When the existing drain does not protrude below the deck, extensions are held in place with brackets bolted to the bottom of the deck and other brackets bolted to the web of the beam (with approval from a bridge engineer).

Figure 2-1
Form Work Support for Full Depth Removal

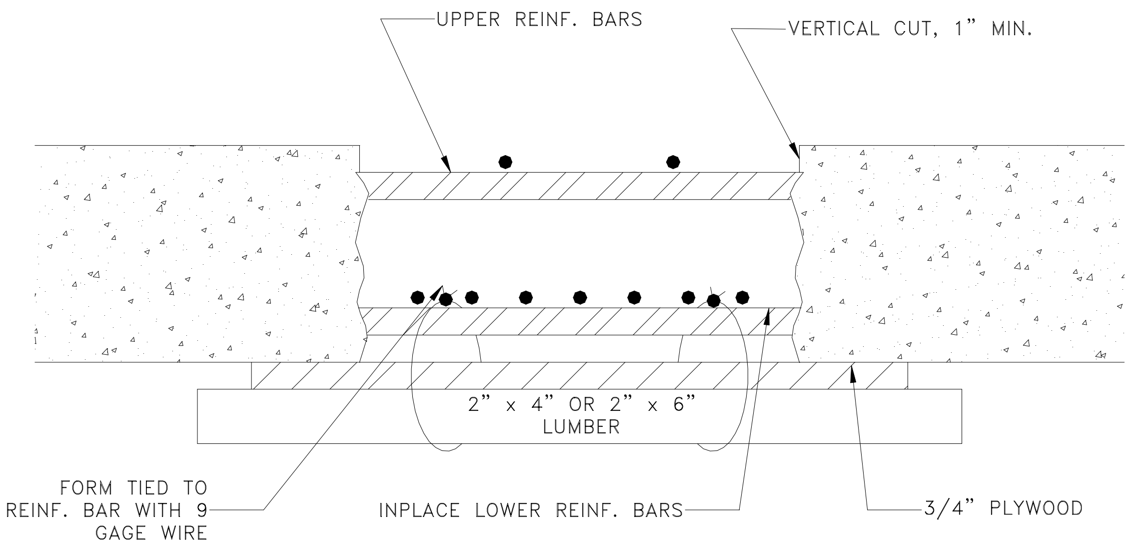
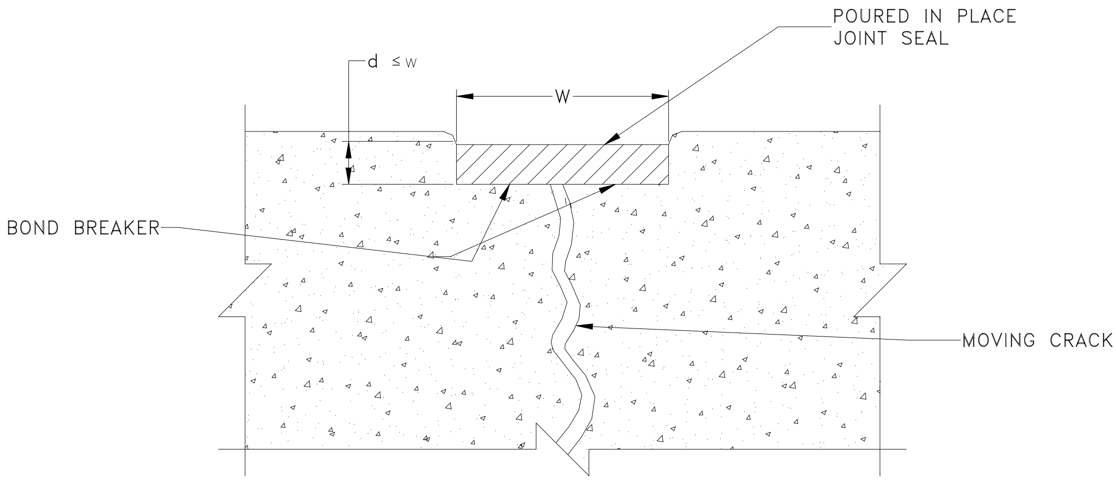


Figure 2-2
Flexible Seal for Working Crack



≤ MEANS LESS THAN OR EQUAL TO

Figure 2-3
Timber Deck Replacement

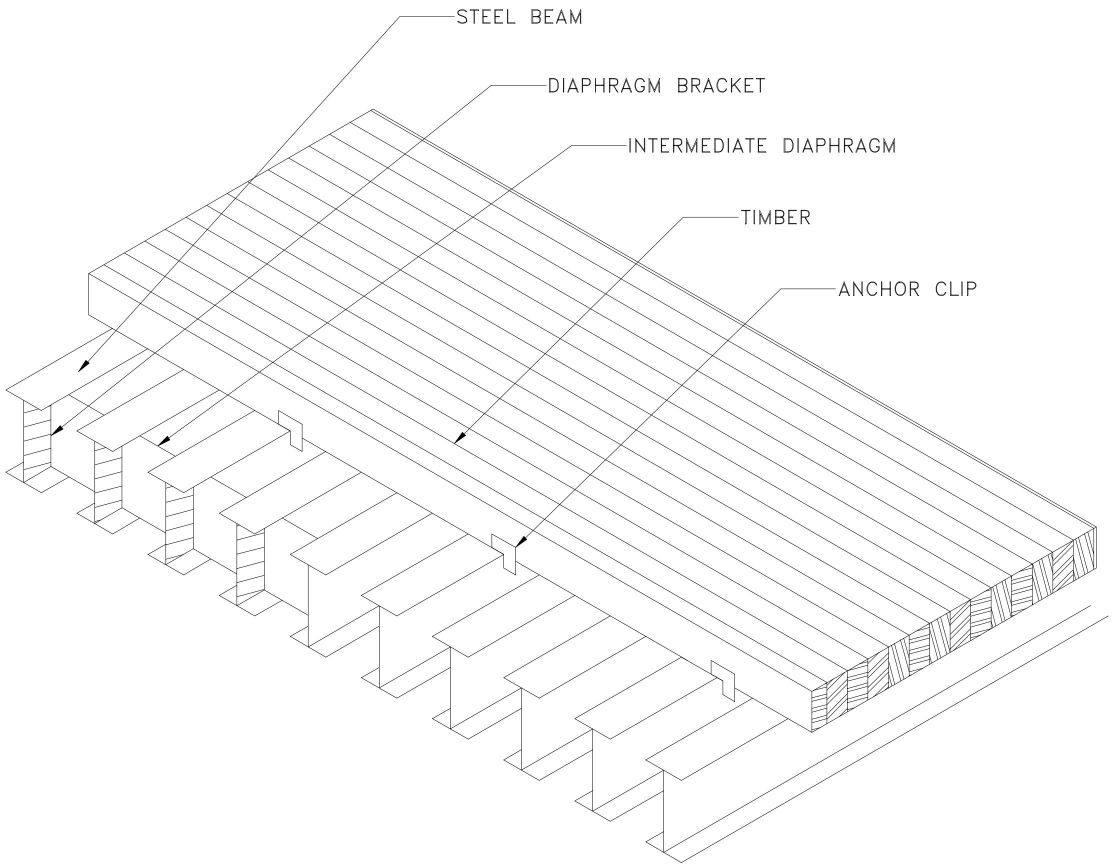


Figure 2-4
Mudjacking

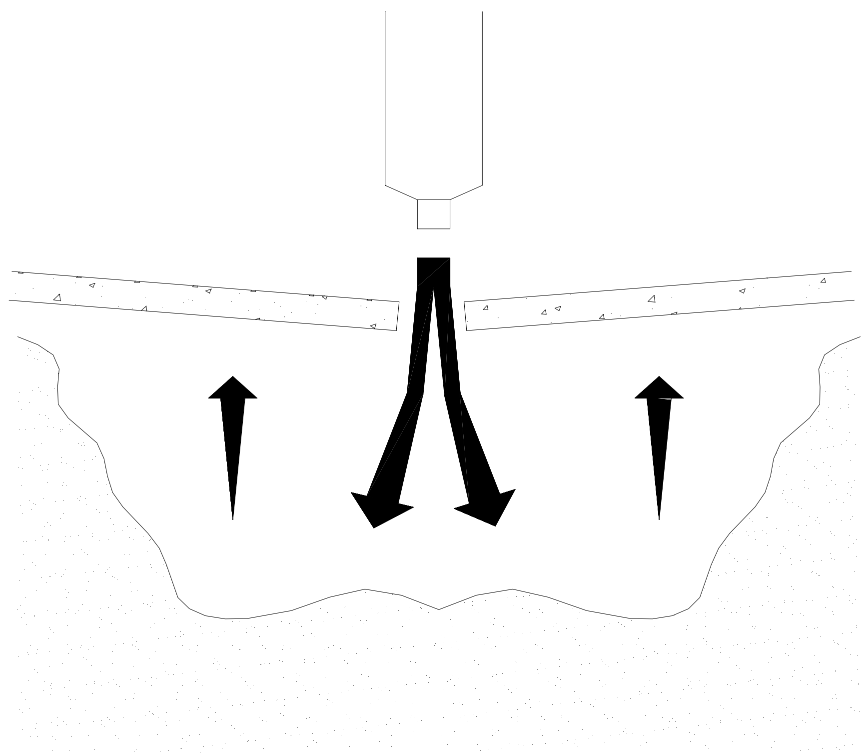
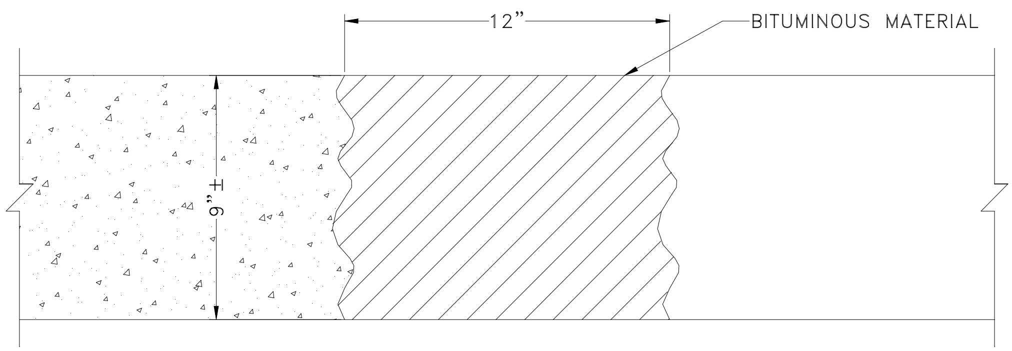


Figure 2-5
Relief Joint



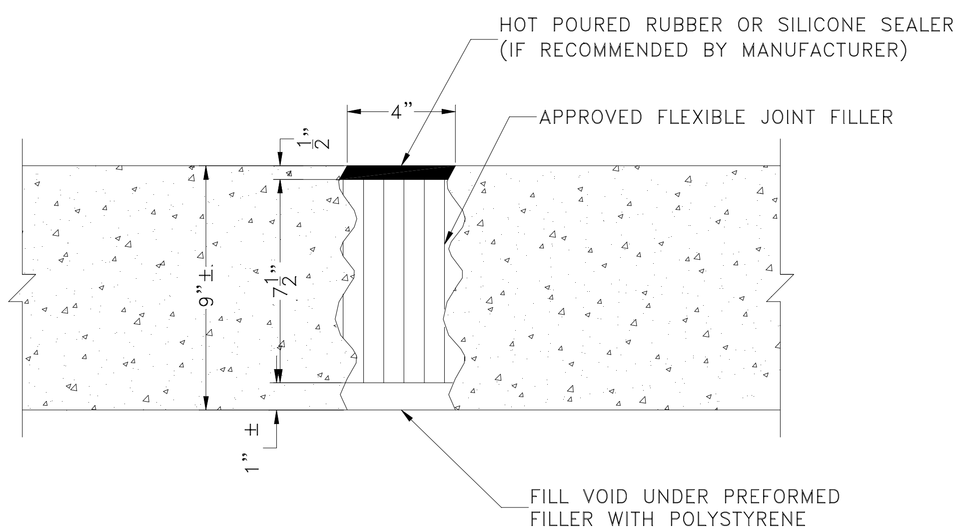


Figure 2-6
Narrow Relief Joint

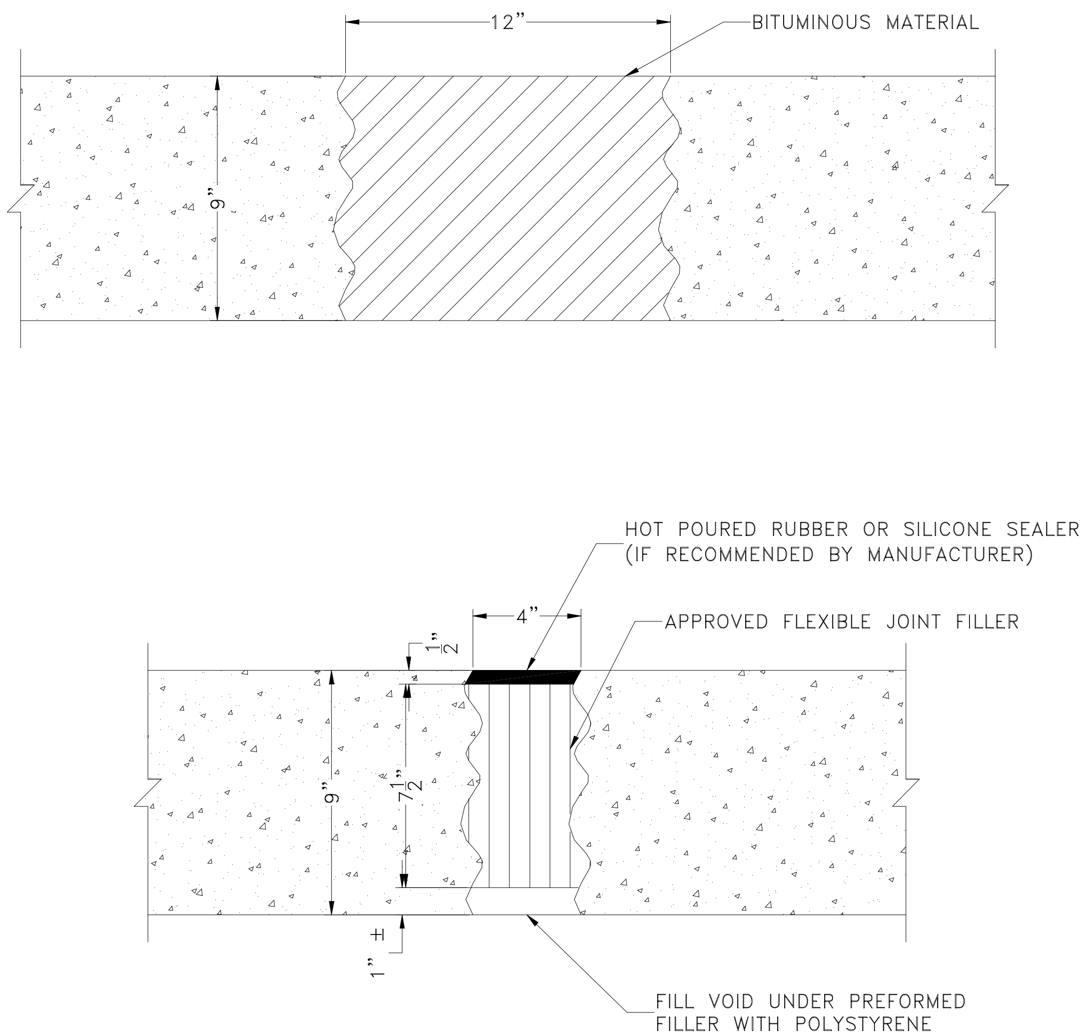


Figure 2-7
PVC Deck Drain Installation

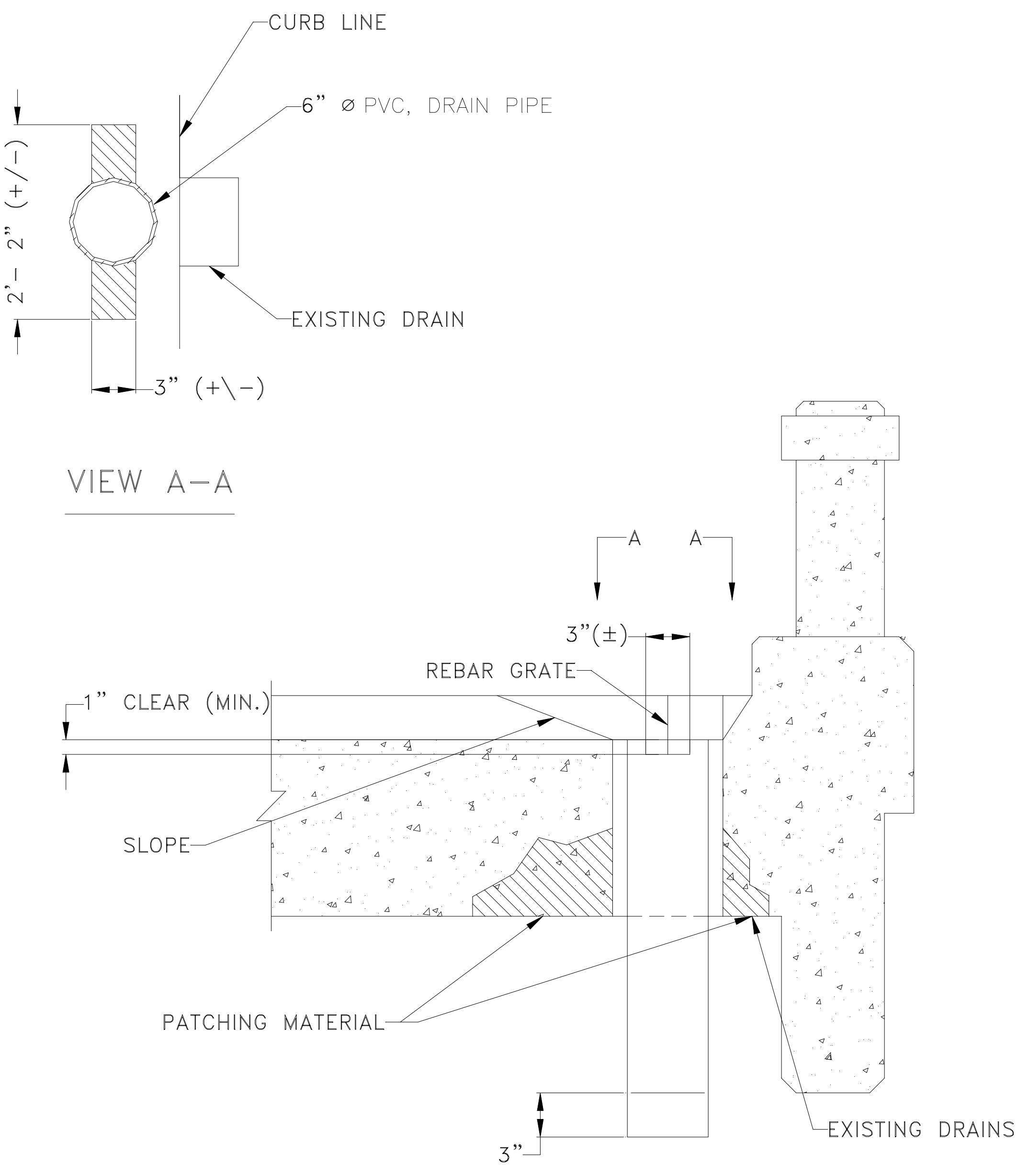
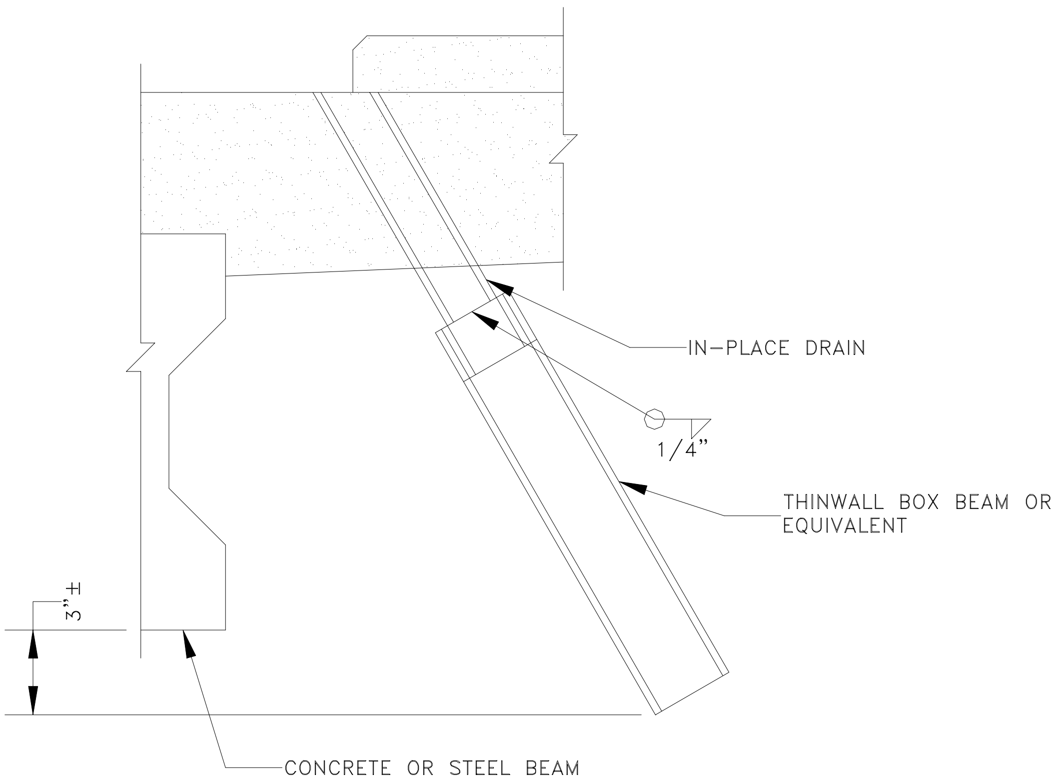


Figure 2-8
Drain Extension



CHAPTER 3

RAILING

3.1 CONCRETE RAILING

3.1.1 Concrete Rail Maintenance

The concrete rail is as susceptible to cracks and spalls as the deck. It is important to protect the surface and seal cracks. The same methods of crack seal can be used on the rail as on the deck. Since the rail does not receive the same traffic wear as the deck, there are more options for protective coatings, such as white epoxy that reflects light, waterproofs the rail and also enhance its visibility.

3.1.2 Concrete Rail Repair

A patch may be adequate for small areas of damage. Procedures for patching concrete are included under Deck Maintenance and Repair.

A. Recommended Methods

If one or more sections of rail or posts are broken, the procedure for concrete rail repair includes the following steps:

1. Assuming that the rail will be replaced "in-kind", which is a decision that should be made by a qualified bridge engineer, the plans should be obtained for use in constructing the new sections.
2. Remove concrete in sections of post and rail to be replaced using jackhammer and acetylene torch.
3. Straighten or position existing steel as needed for the replacement section.
4. Splice and replace reinforcing steel as needed.
5. Form new sections to conform to rail dimensions on plans.
6. Place the concrete.
7. Cure concrete for at least 72 hours.
8. Finish concrete with a rubbing stone to match existing rail and clean up the job site.

3.1.3 Electrical Conduits

Electrical conduits imbedded in concrete railings are exposed at the expansion joints. Slip joints in the conduit should be protected to prevent corrosion that may impair the function of the joint. Frequent inspection and maintenance of the protective coating is recommended.

3.2 STEEL PIPE AND TUBULAR RAILING

3.2.1 Steel Rail Maintenance

Most steel rail is galvanized and maintenance is minimal. Areas of concern are where the steel is in contact with concrete or other metals. To prevent corrosion, these areas should have an insulating material to protect the steel. If painting is required, a zinc-rich coating is recommended. See Figure 3-1 for typical sections of steel rail mounted on concrete.

3.2.2 Steel Rail Repair

Metal rail is fabricated in standard sections and most bridges are designed with one of the standard sections. It is a good idea to have an inventory of common sections, with necessary hardware, for replacement needs.

A. Recommended Method

Repair and replacement of steel pipe and tubular railings should be made as follows:

1. Collision-damaged steel railings generally have to be replaced. Occasionally this type of railing can be straightened and repaired. When delays in receiving new or replacement parts are encountered, a temporary railing repair should be made to protect the public and the Department.
2. Loose anchor bolts and connections should be tightened. If corrosion is present, painting or galvanizing procedures should be followed.

3. Rust stains around the perimeter of the steel rail posts or anchor bolts imbedded in concrete indicate corrosion. Corroded areas should be thoroughly cleaned and painted. Railing components that have a section loss should be repaired or replaced.
4. Hot-dip galvanizing is recommended for new, replacement, or existing railings. Zinc-rich paint may also be used. Painted railing will require frequent repainting when located in industrial or marine environments. Care should be taken to touch up the protective coating after tightening the nuts on anchor bolts and other rail connections.
5. Damaged anchor bolts should be repaired or replaced as required. Where anchor bolts must be extended, chip away the concrete around the bolt to allow welding below the finished surface of the concrete. Old bolts should be cut and ground at an angle to provide a stronger weld. Replace damaged concrete or concrete that has been removed as repairs are made. Large areas justify concrete replacement after the railing has been repaired.

3.3 ALUMINUM RAILING

3.3.1 Aluminum Rail Maintenance

Oxidation protection is required at contact surfaces between aluminum railing components and dissimilar materials to which the railing is attached. Steel to aluminum contact surfaces should be caulked with an elastic, non-staining blend of water-repellent oil, asbestos fiber and flakes of aluminum, metal or other suitable materials. The contact surface of each aluminum railing post attached to concrete should be separated from the concrete with a non-reactive bedding material such as a 30# non-perforated, asphalt-saturated felt, galvanized or painted steel plate, or an elastomeric caulking compound.

3.3.2 Aluminum Rail Repair

The repair procedures vary in detail but general guidelines include the following:

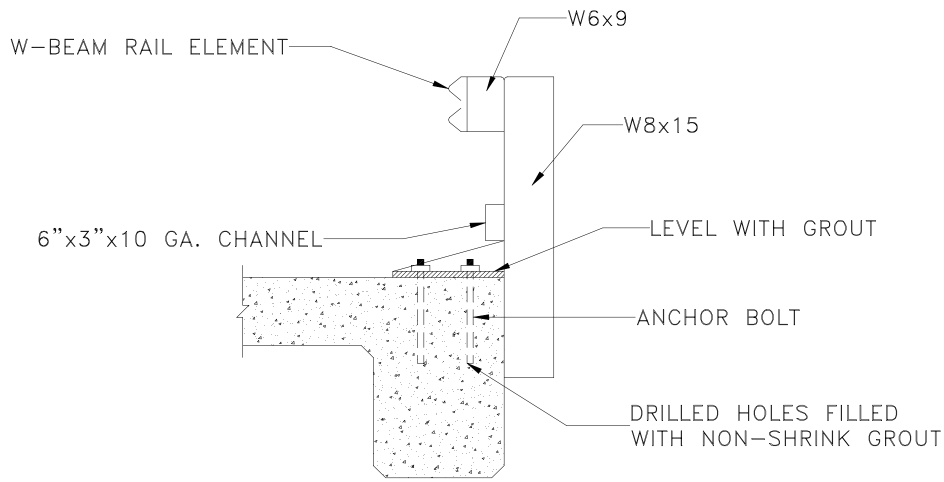
A. Recommended Method

1. Aluminum railing damaged by collision should be repaired or replaced promptly to restore the railing to its original design strength. New railing sections are generally preferred

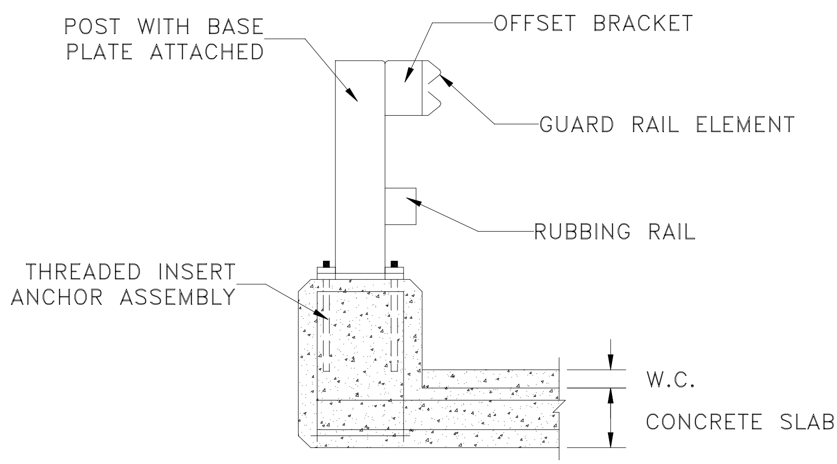
because of the lack of personnel experienced in straightening or welding aluminum. Consideration should be given to replacement with non-pocketing or "New Jersey" type concrete railing.

2. Anchor bolts and connections should be inspected and repaired in the same manner as steel railing.

Figure 3-1
Steel Guardrail Mounted To Concrete



STRUCTURE MOUNTED GUARD RAIL



CHAPTER 4

SUPERSTRUCTURES

4.1 PREVENTIVE MAINTENANCE

Regular cleaning of the bearings and superstructure members is necessary to remove accumulation of sand, debris, bird droppings, and other harmful material by flushing with high-pressure water jet or compressed air, sweeping, or shovel.

Bearings transmit the dead load of the superstructure and the live (traffic) load to the substructure (abutments and piers), while permitting the superstructure to undergo the necessary movements without developing overstresses. The movements are caused by temperature change, wind pressure, substructure movement and the deflections from the loading. A bearing that is so badly corroded or fouled that the parts will not move relative to each other, as originally intended, is said to be "frozen". A bearing assembly that is frozen, out of position, damaged, or otherwise inadequate, may overstress the bridge seat, beam ends, columns, or other members of the bridge and must be repaired or replaced. Preventative maintenance, or periodic cleaning can prolong the service life of the bearing assembly and prevent more costly damage to the bridge superstructure and substructure.

4.1.1 Cleaning

A. Recommended Method

Clean with high-pressure water/air or mechanical devices.

1. Set up scaffolding or ladders, or under bridge equipment as required.
2. Thoroughly flush all bearings and bearing seats at piers and abutments with high-pressure water/air to remove dirt and debris.
3. Scrape, brush or chip all accumulated debris that cannot be removed by high pressure water/air flushing.

4.1.2 Spot Painting

A. Inorganic Zinc Paint System

1. All corroded areas are to be cleaned by an approved method to a "near-white" condition.
2. Coat the cleaned areas by brush or spray with a single coat (3.0 to 5.0 dry mils) of zinc-rich primer.
3. 12 to 24 hours after application of the primer coat, apply finish coat to a minimum dry film thickness of 3.0 mils. Bridges located in coastal areas require an intermediate coat prior to application of the finish coat.

B. Oil Base Paint

1. All corroded areas are to be cleaned by an approved method to a "commercial" blast or wire brushed.
2. The cleaned areas shall then be painted by brush or spray with two coats (min. 2.5 mils dry film thickness per coat) of Florida Specification Code Z-C Primer.
3. A minimum of 48 hours shall elapse between first and second coat of primer.
4. After second coat of primer has cured 48 hours, apply by brush or spray one coat (0.5 mils min. dry film thickness) of Florida Specification Code B-A Aluminum Topcoat.

C. Precautions

1. Precautions must be taken not to damage the paint system outside the deteriorated area being repaired. This may be accomplished by shielding if necessary, however any damaged areas from over-blast must be repaired.
2. Site specific technical special provisions are required for each structure on which the existing coating system contains lead. Reference the CPAM and the SDG.

4.2 BEARING MAINTENANCE AND REPAIR

There is a wide variation in types of bearings that have been used on bridges, from simple sliding plates to elaborate rack and pinion arrangements. Advanced materials such as Teflon, neoprene, and high strength and stainless steels have resulted in these materials being used in modern bearings in an attempt to provide reliable, trouble-free operation. There are two general types of bearings:

- Fixed Bearings - Resist lengthwise movement of the bridge but permit rotation of the superstructure due to deflections or bending.

- Expansion Bearings - Permit both lengthwise movement, mostly caused by expansion and contraction due to changes in temperature, and the rotation of the superstructure due to deflections or bending.

Bearing problems include frozen surfaces that transmit tremendous forces to other parts of the bridge, misalignment, movement beyond the design capabilities, and material failures. The cause of most bearing problems are often leaking deck expansion joints, substructure movement, or approach roadway movement, which results in pressure on the superstructure. Listed below are common problems encountered on some of the more common types of bearings.

4.2.1 Sliding Plates

The most common problem with sliding plates is friction caused by corrosion. The friction can transmit enough force to the anchor bolts to crack the bridge seat. The only other significant problem is related to excess movement, sliding the plate too far in one direction. If the bearing is corroded or movement is prohibited, the bridge must be jacked so that the plate surfaces can be removed, thoroughly cleaned, lubricated, and repositioned. Whenever the plates are removed and disassembled they should have grease fittings installed to facilitate future maintenance.

4.2.2 Rollers

Most roller bearing nests are enclosed and maintenance is difficult. Some are enclosed in a sealed system with lubricants. Maintenance involves keeping the area around the bearing clean and painted. Lubrication is limited to keeper links and/or nesting mechanisms that require disassembly. If the rollers stop functioning they must be removed and refurbished. To accomplish this the end of the span must be jacked. Since the roller nests normally have to be rebuilt in a shop, it is desirable to fabricate an extra one to avoid closing the bridge for extended periods of time.

4.2.3 Rockers

Maintenance includes keeping the assembly clean, lubricated, and painted. If pins become worn or corroded and movement is a problem, they should be removed and replaced or cleaned and lubricated. Jacking is necessary to remove the pin.

4.2.4 Pin and Hangers

Located under a deck expansion joint, the pin and hanger assembly is susceptible to corrosion. The corrosion causes the assembly to freeze, preventing movement and transmitting tremendous forces to the pin and hanger, which may result in a torsional failure of either the pin or hangers. Pin and hanger assemblies present a problem in that corrosion of the pin and its bearing surface cannot be easily detected without disassembly, and this is not feasible. The best maintenance for a pin and hanger bearing assembly is to keep the deck expansion joint above the assembly properly maintained.

4.2.5 Elastomeric Pads

Maintenance is rarely necessary unless the bearing pad fails or walks out of position due to expansion and contraction of the superstructure. To correct these problems the bridge must be jacked and the elastomeric bearing pad replaced or repositioned. If slippage is a continued problem, an abrasive could be added to the contact surface or a keeper plate could be attached to the seat. Excessive deformation is present when the longitudinal displacement is greater than 25 percent of the pad height.

4.2.6 Pot Bearings

Keeping the bearing area clean and free of debris is the only maintenance that is normally required with pot bearings. When they malfunction, the structure must be jacked, and the bearing removed and replaced or repaired.

4.3 JACKING AND SUPPORTING THE SUPERSTRUCTURE

Bridge bearing repair and rehabilitation procedures often require jacking the superstructure. Since serious damage may result from an improper jacking operation, it is extremely important that this operation is correctly planned and accomplished. Improper jacking can result in collapse of the bridge, serious structural damage to the bridge, injury to workers, or a traffic accident. The District Structures & Facilities Engineer must approve bridge jacking operations.

4.3.1 Jacking Precautions

A. Precautions

1. The jacks and the jacking supports must be straight, plumb and of adequate capacity to support the part of the bridge being lifted.
2. Construct the necessary bents and cribbing to support the jacks when it is not possible to locate the supports on the existing substructure. An adequate foundation to prevent differential settlement is very important.
3. Reinforce bridge members as necessary to withstand the force of the jacks.
4. Disconnect railings and utilities if necessary.
5. Place jacks snugly into position.
6. Restrict traffic on the span while it is supported by jacks. When it is not feasible to restrict traffic during the jacking operation, the live load on the jacks must be considered. Protect the deck expansion joints and provide a smooth transition to the span with steel plates if traffic is allowed.
7. Raise the span by jacking. Pressure gauges should be used to ensure that all the jacks are lifting the span evenly.
8. Use observers placed at strategic points to look for signs of structural distress.
9. Jack, block, and re-jack until the required position is achieved.
10. Check periodically for differential settlement.
11. Remove the blocks using the jacks after the repairs are completed.
12. Ensure that deck expansion joints are functioning properly, that the alignment is not altered, that there is adequate space for expansion without debris or restriction, and that the seal is watertight after the span has been lowered.

4.4 BEARING REPAIR & REHABILITATION

A registered professional engineer shall approve all bearing repair and rehabilitation procedures.

4.4.1 Proper Position

When setting or resetting bearings, they should be positioned so that they are centered at the median temperature (21 degrees Celsius in Florida). The distance off center can be adjusted for other temperatures by multiplying the following formula by the degrees difference in the temperature from median:

$$D = \triangle t \times L \times C$$

Where:

D = Distance off center, mm or m (dependent on the units for L)
L = Length of Span(s), mm or m
$\triangle t$ = Temperature range from median temperature (21°C)
C = Coefficient of Thermal Expansion
= 0.0000117 for steel superstructures
= 0.0000090 for concrete superstructures

4.4.2 Resetting

A bearing assembly that is frozen or misaligned must be repaired or replaced; otherwise it may overstress or damage beam ends, columns or other members. Proper planning for this rehabilitation procedure must be based on a thorough analysis of the causes and conditions that make the rehabilitation necessary. Determine the cause of the problem. When a bearing is heavily corroded or covered with debris, the rehabilitation should include preventive measures.

A. Check for:

1. The deck expansion joint may require rehabilitation.
2. An out-of-position bearing unit may be caused by tilting or settlement of the pier or abutment.
3. Longitudinal forces on the structure from movement of the approach roadway.
4. Superstructure creep forces.
5. Vibration from live loads.
6. Lateral forces on the structure from wind, high water, or an overheight vehicle.

Evaluate the existing bearings to determine if repair, replacement, or rehabilitation is needed. When the causes of the bearing problem are eliminated, often the existing bearings may only need cleaned, lubricated, and repositioned.

The recurrence of frozen bearings may indicate that the design should be modified. Many new elastomeric or pot bearing devices may be substituted for sliding and rolling metal assemblies.

B. The major steps in the bearing rehabilitation are:

1. Construct temporary supports for the superstructure.
2. Close the bridge to traffic.
3. Jack the superstructure to remove the load from the bearings.
4. Remove, clean, and reposition the bearing.
5. Make seat modifications if necessary.
6. Ensure that the bearing is properly positioned for the ambient temperature.
7. Remove temporary supports.

4.4.3 Elevating Bearings to Increase Vertical Clearance

The previous procedure can be modified to increase vertical clearance under the bridge by elevating the bearings using the following steps:

A. Recommended Method

1. Jack and support the bridge slightly above its new elevation while seat and bearing modifications are made. It is important to jack the spans together to avoid damage to the deck joints.
2. Modify the seats to raise the bearings the required distance. The seat modifications may be accomplished with a steel or reinforced concrete pedestal. A bridge engineer should design seat modifications.
3. Modify approaches to match the new position of the bridge deck.

4.5 CONCRETE BEAM & GIRDER REPAIR

4.5.1 Crack Repair

A. Epoxy Injection

1. Clean the cracks by air or brush.
2. Install the ports along the crack and seal all the other cracks with epoxy.
3. After the sealing is cured, begin pumping epoxy into the first port that is normally the lowest port.
4. Continue pumping until epoxy flows from a second port.
5. Seal the first port and begin pumping at the second port.
6. Repeat steps 3, 4 and 5 until all ports are full.
7. Remove ports and surface seal after epoxy has cured.

B. Penetrant Sealer

1. The concrete surfaces shall be prepared for sealing by using high pressure (6,000 psi nozzle pressure) water blasting to remove all traces of dirt, grime, mineral deposits and all other deleterious material.
2. Apply the penetrant sealer in accordance with the specification and the manufacturer's recommendation.

C. Drypacking

Drypack can be used for filling narrow slots cut for the repair of dormant cracks. Repair the crack by hand placement of a low water content mortar followed by tamping or ramming of the mortar into place. The use of drypack is not recommended for “active” cracks.

1. Before a crack can be repaired by drypacking, the portion adjacent to the surface should be widened to a slot about 1 inch wide and 1 inch deep using a power-driven sawtooth bit. The slot should be undercut so that the base width is slightly greater that the surface width.
2. Clean the slot thoroughly.
3. Apply a bond coat, consisting of cement slurry or equal quantities of cement and fine sand, mixed with water to a fluid paste consistency.

4. Make the mortar mix, consisting of one part cement, three parts sand (passing a No. 16 sieve), and just enough water so that the mortar will stick together when hand-molded into a ball.
5. To minimize shrinkage in place, the mortar should stand for 30 minutes after mixing and then remixed prior to use.
6. The drypacking should be placed in layers about 3/8 inch thick. Each layer should be thoroughly compacted over the entire surface using a blunt stick or hammer. Each layer should be scratched to improve bonding with the next layer. There is no need for a waiting period between application of layers.
7. Finish the top surface and the repair should be cured by either water or curing compound.

D. Shear Crack Stitching

Reinforced concrete T-beams often exhibit diagonal shear cracks near the ends of the beams (at the supports). The cracks begin at the base of the beam section, near the bearing, and travel upward, toward the middle of the beam span, at approximately a 45 degree angle. Typical hairline cracks do not require repair. However, numerous large (wide) cracks can be repaired by this post-reinforcement (stitching) method. Refer also to the FHWA report titled, “Cracked structural Concrete Repair Through Epoxy Injection and Rebar Insertion”, FHWA-KS-RD-78-3.

1. Locate and seal all the cracks with epoxy sealing material.
2. Mark the beam centerline on the top of the deck.
3. Locate the transverse deck reinforcement.
4. Vacuum drill a series of 45 degrees holes that avoid the rebars. The direction of drilling is perpendicular to the shear cracks and the spacing varies approximately 6 to 12 inches between holes. See Figure 4-1. If rebar is encountered during the drilling operation, the drilling point should be shifted to another location.
5. Pump the holes and cracks full of epoxy.
6. Insert reinforcing bars into the epoxy-filled holes.
7. Seal holes with epoxy grout.

E. Post-tensioning

1. Concrete Box Girder - Center Web

This procedure is used to repair shear cracks in the center and exterior (non-inclined) webs of concrete box girders. A qualified engineer must design the repair. Refer to the paper, “Cracking in Post-tensioned Concrete Box Girder Bridges”, by Dr. Walter Podolny Jr., in the PCI Journal, 1984.

a. Remove the wearing surface on the box girder in such a manner to allow restoration later.
b. Clean all the cracks and repair the cracks by epoxy injection.
c. Mark with chalk the theoretical location of vertical tendons on the concrete surface.
d. Chip out the anchorage pockets with a lightweight pneumatic hammer. This operation has to be accomplished very carefully as the upper layer of reinforcement and longitudinal tendon ducts may be exposed.
e. At some locations the longitudinal cantilever tendons in the top flange terminate, therefore it is possible to bore a 2 1/4 inch hole through the web to within 10 inches of the bottom of the box. At this point, a gamma ray source is placed in the hole, and at the same time, a sensitive plate is placed underneath the box. If the exposure indicates that there is no interfering longitudinal bottom flange tendon, the drilling is resumed. Where there is interference from either a longitudinal top or bottom tendon, the single post-tension bar is replaced by two bars on either side of the web. See Figure 4-2 and 4-3.
f. Place the post-tension tendon and tension to the required stress.
g. Anchor the bar tendons and restore the wearing surface.

2. Concrete Box Girder - Exterior Web

This procedure is used to repair shear cracks in the inclined exterior webs of concrete box girders. A qualified engineer must design the repair. Refer to the paper, “Cracking in Post-tensioned

Concrete Box Girder Bridges", by Dr. Walter Podolny Jr., in the PCI Journal, 1984.

a. Remove the wearing surface on the box girder in such a manner to allow restoration later.
b. Clean all the cracks and repair the cracks by epoxy injection.
c. Mark with chalk the theoretical location of vertical tendons and inclined tendons in staggered pattern on the concrete surface. Generally the tendons have to be spaced at 7 1/2 inches. (The tendons are staggered in a vertical and inclined orientation to preclude weakening of the top and bottom flanges caused by drilling the holes.)
d. Chip out the anchorage pockets with a lightweight pneumatic hammer.
e. Drill the holes along the predetermined alignment through the flanges of the concrete box girder.
f. Place the post-tension tendon with sheathing tubes into each hole.
g. Drill holes on the web and install the mechanical doweling (expansion bolts) into the web which will support a grid of conventional reinforcement for thickened web.
h. Erect the concrete form work and complete the thickened concrete web.
i. Stress the tendon after the development of the specified concrete strength in the thickened web. See Figure 4-4.
j. Pressure grout the voids in the tendon ducts.
k. Restore the wearing surface.

3. Concrete Box Girder - Curved Soffit

This procedure is used to repair longitudinal cracks resulting from vertical curvature of soffit tendons at the bottom flange of concrete box girders. See Figure 4-5. The repair involves the installation of a hanger/suspension system to support the bottom flange from the upper slab, inside the box girder. See Figure 4-6. A qualified engineer must design the repair. Refer to the paper, "Cracking in Post-tensioned Concrete Box Girder Bridges", by Dr. Walter Podolny Jr., in the PCI Journal, 1984.

a. Inspect the type of cracks carefully to ensure the cause of the problem.
b. Clean the cracks and repair them by epoxy injection.
c. Install the suspension system inside the concrete box girder to support the bottom flange.
d. In some cases, crack width can reach 3/8 inch. The bottom flange cracks can be repaired by jacking the suspension rods at the deck level, producing the external forces to the section to return it to a non-deformed state.

4.5.2 Spall Repair

A. Beam End

This procedure may be used to repair deteriorated ends of concrete beams. Such deterioration is usually caused by excessive thermal forces from frozen bearings. This is a common problem on old T-beam bridges, which often lacked adequate reinforcement in the beam ends. Unless the bearing area of the beam end is affected this type of deterioration does not generally require repair. See Figure 4-7.

1. Restrict traffic from the affected beam.
2. Jack the beam off the support enough to slide a piece of sheet metal under the beam. The sheet metal acts as a bond breaker for the construction of a new beam end. A bridge engineer should review jacking supports and procedures.
3. Remove the deteriorated concrete.
4. Epoxy inject any visible cracks.
5. Place new reinforcement steel and secure to the existing reinforcement steel by welding or mechanical splices. If weldability of the two steels is a concern, use low hydrogen electrodes and preheat the reinforcing bars.
6. Apply epoxy bonding compound to prepare the surfaces of the beam end.
7. After forming, place the new concrete or an approved material. A non-shrink additive should be used in the new concrete.
8. After the concrete has reached sufficient strength, jack all beams simultaneously to sufficient height to install new elastomeric bearing pads.

9. Uniformly lower the end of the bridge. Check for possible distress in the repaired area.

B. Pneumatic Drypack Application

This proprietary method can be used to repair or restore a concrete section which has deteriorated or been damaged by impact. A pneumatic application gun is used to apply the material. The method works well in an overhead work position. Trained personnel in the usage of DRI-PAK-IT Portable Application Gun shall perform this type of repair. Refer to Concrete Repair Specifications published by Cem-Kote Products, Inc. (P.O. Box 1148 Novato, CA 94948-1148) for materials, mix proportions, curing, training, equipment, and cold or hot weather application instructions.

1. Remove all loose concrete and rust scale from exposed reinforcement.
2. Clean reinforcing and concrete surfaces of contamination.
3. Saw cut or chip concrete to form square edges with a minimum depth of 1/4 inch. Clean the surface area with oil-free air.
4. Pre-dampen the concrete surface. Mix a waterproof bonding slurry consisting of fresh pure Portland Type I or II Low Alkali Cement with sufficient hydration liquid to form a brushable thin paint-like slurry.
5. Apply the waterproof bonding slurry by brush on all surfaces and voids. Do not allow bonding coat to dry prior to application of repair material.
6. Using the portable application gun, apply the hydration mixture (Gun-Add with water) and the premixed repair material to the repair area.
7. After completion of the finishing operation, all repairs should be immediately cured with Cem-Kote Concentration curing solution. Do not apply water to repaired surface as this may cause surface checking.

4.5.3 Tendon Splicing

This proprietary method can be used to splice broken prestressing strands which have deteriorated or been damaged by impact. The method works well on AASHTO-type girders, but can also be used on piling. Contact Prestress Supply, Inc., in Lakeland, Florida for the GRABB-IT splice assembly and detailed instructions. See Figure 4-8.

A. Recommended Method

1. Thoroughly clean spalled and deteriorated concrete in the damaged area.
2. Install the GRABB-IT splice assembly. If the existing strand is damaged for some length, a new strand section can be installed using the GRABB-IT splice and a splice chuck.
3. Torque splice to desired tension based on specifications, or estimate tension if specifications are not available:

    a. For 7/16 inch strand use 18.9 kips
    b. For post-1980 1/2 inch strand use 28.9 kips
    c. For pre-1980 1/2 inch strand use 25.2 kips

    (The GRABB-IT splice assembly also comes with a torquing chart which gives correct values for the desired tension, for each strand size.)

4. Restore the spalled area using epoxy grout or other approved material.
5. Epoxy inject all cracks, Class 2 or larger.
6. The damaged prestress concrete beam can also be strengthened with external post-tensioning by additional strands along the bottom flange. For this method refer to NCHRP Report No. 280.

4.6 STEEL BEAM & GIRDER REPAIR

4.6.1 Corrosion Repair

The corroded ends of steel beams are repaired by cutting out the damaged portion and replacing it with a new WT section or build-up plate section.

This method is suitable only for simply supported spans. The top flange and a part of the web must be sound. The steel must be weldable. All beams must be lifted simultaneously whether they are to be repaired or not. A qualified bridge engineer should design the welding or bolting details.

A. Recommended Method

1. Relieve the load at the bearing by jacking under the sound portion of the beams.
2. Cut out the corroded area. See Figure 4-9. Bearing stiffeners must be removed if present.
3. Weld the new section into place using full penetration welds. The new section may be either a suitable WT or be shop fabricated from other suitable shapes. Replace the bearing stiffeners where required. Fatigue problems may result from welds. A bolted connection for the new section attachment is preferable.
4. Lower the span to bear; check for distress.
5. Remove jacking equipment and other temporary supports.
6. Paint all areas exposed to cutting and welding for corrosion protection.

4.6.2 Crack Repair

This method can be used to retrofit the cracks at the fatigue-prone areas by strengthening steel beams where the web has cracked. A qualified bridge engineer should handle the design detail.

A. Recommended Method

1. Locate ends of cracks in beam web using lquid dye penetrant.
2. Field drill a 15/16 to 1 1/4 inch diameter hole at end of each crack. (Match the hole size to that required for the new high strength bolts.)
3. Pre-cut web stiffener plate 1/8 inch thicker than web to fit area to be strengthened.
4. Field drill bolt holes to fasten plate to stringer web.
5. Paint steel plates and bolts with approved paint (two coats) both sides.

4.6.3 Strengthening

A. Cover Plates

Cover plates can be added to the full-length of existing non-composite simple steel beam spans to increase the load carrying capacity. The cover plates should be attached to the beam using high strength bolts. The use of welded cover plates should be avoided. If welded cover plates are used, the welds must be fully inspected using non-destructive testing. Partial-length welded cover plates are prohibited.

1. Recommended Method

   a. Design the cover plates to achieve the desired capacity. Check the stresses in the modified section to assure adequacy of the existing beam.
   b. Layout the cover plate and shop-drill the bolt holes.
   c. Close the bridge to traffic while it is being supported by jacks.
   d. Clamp the cover plate to the underside of the bottom flange of the beam. (Plates may also be added to the underside of the top flange.)
   e. Calculate the load that would be necessary to jack the center of the span to eliminate the dead load deflection. The beams should be raised by exactly that amount at midspan.
   f. Place temporary supports and jack all beams simultaneously.
   g. Using the cover plate as a template, drill bolt holes in the beam flange. Install bolts to a snug hand-tight fit as the drilling progresses.
   h. Tighten bolts to required tension.
   i. Remove jacking equipment and other temporary supports.
   j. Paint cover plate and beam flange.

B. Post-tensioning

Post-tensioning tendons are mounted at each side of the web by steel brackets and prestressing force is applied to strengthen the steel beam.

The required prestressing force, the location, and the diameter of tendons shall be determined through detailed structural analysis. Corrosion protection shall be provided for the tendons.

1. Attach the post-tensioning brackets (or twin angles) at the predetermined location on the web by high-strength bolts. See Figure 4-10.
2. Install the post-tensioning tendons to the brackets.

3. Apply the required prestressing force to the tendons by hydraulic jacks.
4. Anchor the post-tensioning tendons to the brackets.

C. King-post Truss

High strength steel rods may be used to increase the load carrying capacity of a steel beam (easily adaptable for wood beams also). Two techniques may be used: a) providing vertical supports at one or two positions along the beam, and b) prestressing the lower flange with a small vertical force at the king-post.

Attachments of the steel rod at the ends of the steel beam must be carefully designed to transfer the tensile forces in the rods to the steel beam. Clearance under structure is lessened by depth of king-post. Consideration must be given to induced local stresses in the beam by the intermediate support. Corrosion protection should be provided for the rods. A qualified bridge engineer shall design the detail of the strengthening method.

1. Technique A

   The rods are placed with as much slope as feasible and attached to the ends of the beam at mid-height. The midspan support should be as deep as practical for the site. See Figures 4-11 and 4-12.

   a. Bolt end anchors to the beam web in the desired position. The end anchors must project far enough out from the web to provide clearance between the lower flange and rods.
   b. Attach the king-post support.
   c. Place and tension the rods to the desired level of stress.

2. Technique B

   The high strength rods are placed parallel (or nearly so) to the bottom flange. These rods are then tensioned so as to place a compressive prestress in the lower flange of the beams.

a. Design the rods and attachments to carry the intended post-tensioning forces.
b. Bolt the end anchors for the high strength rods to the lower flange of the steel beam. A short center support may be used to provide a small vertical force at midspan.
c. Place the high strength rods through the anchors and tension to the desired stress level.

4.6.4 Replacement

For either composite or non-composite construction where a beam has been damaged by collision or corrosion. The top flange must be in sound concrete and in good condition.

A. Recommended Method

1. Limit traffic to light vehicles and direct to far side of bridge roadway until completion of repair.
2. Jack the bridge so that the damaged beam is clear of the bearing surface.
3. If necessary, provide temporary support adjacent to the beam to be removed.
4. Remove the damaged portion of the steel beam from the bridge slab by cutting through the web directly below the top flange. The top flange must remain in the concrete slab.
5. Grind the bottom face of top flange smooth.
6. Select or fabricate a replacement beam having a top flange width smaller than that of the original beam to allow for welding.
7. Weld the new steel beam in place with continuous fillet welds.
8. Remove temporary supports if used.
9. Seat the new beam and remove the jacking equipment.
10. A bolted cover plate may be advisable on the new beam to lower the neutral axis and thereby reduce the lower flange flexural stress. A qualified bridge engineer should perform the design.
11. Welding should only be done by a welder certified for type and position of the welds required.

4.7 TIMBER BEAM REPAIR

Any crack in a timber bridge beam (stringer) causes a loss of load-carrying capacity and may require immediate repair or replacement before traffic can use the bridge. Timber beams with a longitudinal crack can be repaired by clamping it together with steel plates top and bottom, held together by bolts that extend the height of the beam. Normally though, replacement is the most cost effective repair of decayed or damaged timber beams.

4.7.1 Crack & Split Repair

Steel plates and bolts are used to prevent further deterioration of cracked timber stringers. Repair is limited to situations where it is not desirable to move the deck planks. Deck planks should be in good condition. Repair hardware will have to be removed if deck is replaced.

A. Recommended Method

1. Close bridge to traffic during the repair period.
2. Calculate the load that would be necessary to jack at a location near the cracked position in the beam to eliminate the dead load moment. Calculate the corresponding deflection this load would produce. The beam to be repaired should be raised exactly that amount.
3. Remove the asphalt overlay in the area where the holes are to be drilled.
4. Drill holes for draw-up bolts. See Figure 4-13.
5. Place the retaining and support plates and tighten the draw-up bolts.
6. Replace the wearing surface.

4.7.2 Replacement

Replacement of timber beams is accomplished using one of two general methods. The first method is accomplished without the need to remove the timber deck planking, while the second method involves the removal of the decking.

A. Under Deck Method

Use this method to replace a deteriorated beam or the addition of a helper-beam(s) adjacent to the damaged beam.

1. Locate work platform or work barge as needed.
2. Place two jacks on each cap in adjoining bays next to beam to be replaced. See Figure 4-14.
3. Use steel plates under deck to jack against and remove cross bracing between beams.
4. Remove traffic from jacking area if possible.
5. Jack up until beam clears cap 1/4 to 1/2 inch.
6. Cut wedge out of one top corner of beam and bevel corners on other end. If the new beam is warped, always place camber up to provide bearing on all deck planks.
7. Place wedged end of beam on cap far enough to allow opposite end to be placed on other cap.
8. Place a come-along cable or chain around cap at beveled end of beam and attach to wedged end of beam.
9. Pull beam with come-along to final position.
10. Remove jacks and come-alongs.
11. Fasten cross bracing if necessary.
12. Nail cut wedge at wedged end of beam and install deck planks.

B. Above Deck Method

In some cases, a temporary repair can be made by re-using the beams. If the damaged area is relatively small, the beam can be turned over. This is only done when a new beam is not available because the result is still a weakened beam with a shorter service life when compared to a new beam.

1. Cut decking down along centerline of beams adjacent to beam to be replaced.
2. Remove decking with enough space to replace the deteriorated beam.
3. Jack new beam to final position.
4. Replace decking, nailing to new beam and adjacent beams.
5. A qualified bridge engineer shall approve the jacking method.
6. The jacking operation should be handled by qualified personnel.
7. All work shall be treated with preservative.

4.8 BEAM HELPERS

4.8.1 Carrier Beam Construction

Provides temporary support for severely damaged beam using a steel carrier beam, tension rods, and channel beams. This method is recommended for situations where immediate action must be taken to prevent the collapse of a beam by providing a temporary suspension system for the damaged beam. Shown here is a method for prestressed concrete AASHTO girders, a member type which is frequently damaged by over-height vehicles. The method can be easily modified for other types of beams.

A. Recommended Method

1. Restrict traffic from the damaged beam. Erect a temporary concrete parapet barrier.
2. Remove loose concrete from the damaged beam. Place burlap over the damaged beam section to prevent loose concrete from falling onto traffic below.
3. Design the steel carrier beam for all service moments of the damaged beam, dead load moments of the carrier beam, and the temporary parapet barrier.
4. Determine the locations along the damaged concrete beam where tension rods and channel beams will be used to transfer the loads to the carrier beam.
5. Place the carrier beam on hardwood blocking directly above the damaged concrete beam.
6. Provide hardwood blocking under the carrier beam at each tension rod and web stiffener location to provide buffer to the deck and the carrier beam. See Figure 4-15.
7. Provide angle bracing to support the carrier beam by welding the angle to the top flange of the carrier beam and secure the angle to the bridge curb. See Figure 4-16.
8. Drill holes through the deck along both sides of the steel beam flange at the pre-determined tension rod locations.
9. Place the channel sections beneath the damaged beam and install the tension rods. See Figure 4-17.
10. Tack weld the channel beam to the carrier beam and drypack the drilled deck hole with stiff grout.

4.8.2 Saddle Beam Construction

A permanent repair to restore adequate bearing for beams that have deteriorated beam ends or bearing seats. Fabricate and install a structural steel saddle to fit over the cap and under the beam ends. A qualified bridge engineer should design the saddle beam.

A. Recommended Method

1. Check plans for width of beam and cap or obtain field measurements.
2. Design saddle.
3. Fabricate and paint saddle members.
4. Prepare top of cap on both sides of beam and bottom of beams for good bearing contact between saddle and concrete.
5. Cut neoprene bearing pads to cover concrete cap areas in contact with the saddle on both sides of the beam. Also prepare pads for areas between bottom of beams and saddle.
6. Set saddle members at right angle to cap on each side of beam on top of neoprene pad.
7. Drop one bolt through holes in each end of set members. Hang sections under beam, placing bearing pads before tightening bolts.
8. Install remaining bolts and tighten until 100 percent bearing is obtained under beams or beam is raised to desired elevation.

4.9 TRUSS MAINTENACE & REPAIR

Refer also to the Bridge Maintenance Training Manual, FHWA-HI-94-034, Chapter XIII, *Superstructure Maintenance Procedures,* Section D, *Truss Repair.*

Truss bridges are now rare in the State of Florida. Repair normally consists of replacing a damaged member or strengthening weakened members by adding steel plates. Welding should be avoided if possible in repairing old trusses since the steel has a high carbon content. A qualified bridge engineer should be involved to make this assessment and to develop the repair methods. The method of temporary support during the repair is very different depending on whether the damaged member is in tension or compression.

All steel trusses are susceptible to damage by rust and corrosion. Through trusses and pony trusses are generally narrow and are particularly susceptible to collision damage.

A. Common Repairs

Common repair procedures used to correct truss deficiencies include:

1. Members damaged by rust or corrosion, to the extent that they are overstressed, are repaired by adding strengthening plates to compensate for loss of section at the affected area.
2. Temporary repairs may be made to impact-damaged truss members by using struts to reinforce damaged compression members and cables with turnbuckles to accept part of the load on damaged tension members. Fractured members usually require partial or total replacement.
3. A fractured eye-bar of a pin-connected truss can also be repaired temporarily with a cable to accept part of the stress, but a permanent repair will require replacement of the member.

4.9.1 Replacement of Tension Members

Diagonal tension members are damaged by corrosion, overload, or impacts from oversized vehicles.

A. Recommended Method

1. Design and acquire a replacement section that meets the capacity requirements - including the additional load of the repair activity.
2. If the bridge is open, restrict traffic to one lane on the opposite side of the bridge.
3. Cut and install the wood blocking.
4. Install a cable having the capacity to carry the full dead load in the diagonal plus the live load distributed from the restricted traffic. See Figure 4-18.
5. Tighten the cable system.

6. Remove and replace the damaged member. If the old and new member consists of more than one section, the sections should be removed and replaced individually, using high-strength bolts and keeping the load as symmetrical as possible.
7. Install the batten plates or lacing bars at the required intervals along the diagonal and tighten the high strength bolts in the new member.
8. Remove cable support and other temporary components and restore the bridge to normal traffic conditions.

A vertical tension member can be repaired using the same type of cable support and the same procedure. Damaged diagonal tension members consisting of two eye-bars can be replaced by using rods with U-bolt connections. See Figure 4-19.

4.9.2 Replacement of Compression Members

The difference between replacing a compression member and replacing a tension member is that a heavier and more extensive temporary support system is needed.

A. Recommended Method

1. The temporary support system must be capable of supporting the compression load while the member is removed and replaced. Therefore, each member that makes up the temporary support system will consist of a larger, “column-like” section.
2. To provide room for removing the old compression member, the temporary support must be framed around the old member. It is not mandatory that the temporary support be more than one column; however, since the temporary support is offset, it must be able to resist the unbalanced load that is created when the old member is removed.
3. The load on the damaged member is relieved by jacking as the temporary support is installed. The temporary support is designed to support the jacks.
4. The old member can be used as a template for the fabrication of the new member.

4.9.3 Repair of Damaged Truss Members

If the damage is localized, such as a transverse crack in one of two channels that make up the bottom chord of a truss, a splice can be designed by a qualified bridge engineer. See Figure 4-20.

A. Recommended Method

1. Bolt a side plate to the damaged member. Remove any rivet heads that would interfere with the splice plate if the repair is near a connection. The plate should be centered over the damage.
2. If necessary, remove old tie plates (or lacing bars) from the two channels in the area of the crack to allow placement of the bottom tie plate. Some temporary lateral bracing may be required prior to completing the repair.
3. Bolt the bottom tie plate to the member.

4.9.4 Modifying Portal Bracing

On many older trough trusses, the vertical clearance is restrictive for today's larger trucks. The clearance is controlled by the portal brace connected to the top chord and endpost at both ends of the span. The primary purpose of the portal brace is to support the truss against wind loads; however, it may have been designed also to provide support against buckling to the endpost. A modification of the portal brace can be made to increase the vertical clearance. The portal modification should be designed by a qualified bridge engineer, making sure that the capacity of the endpost is checked since the unsupported length will change.

Figure 4-1
Repair of Shear Crack By Stitching

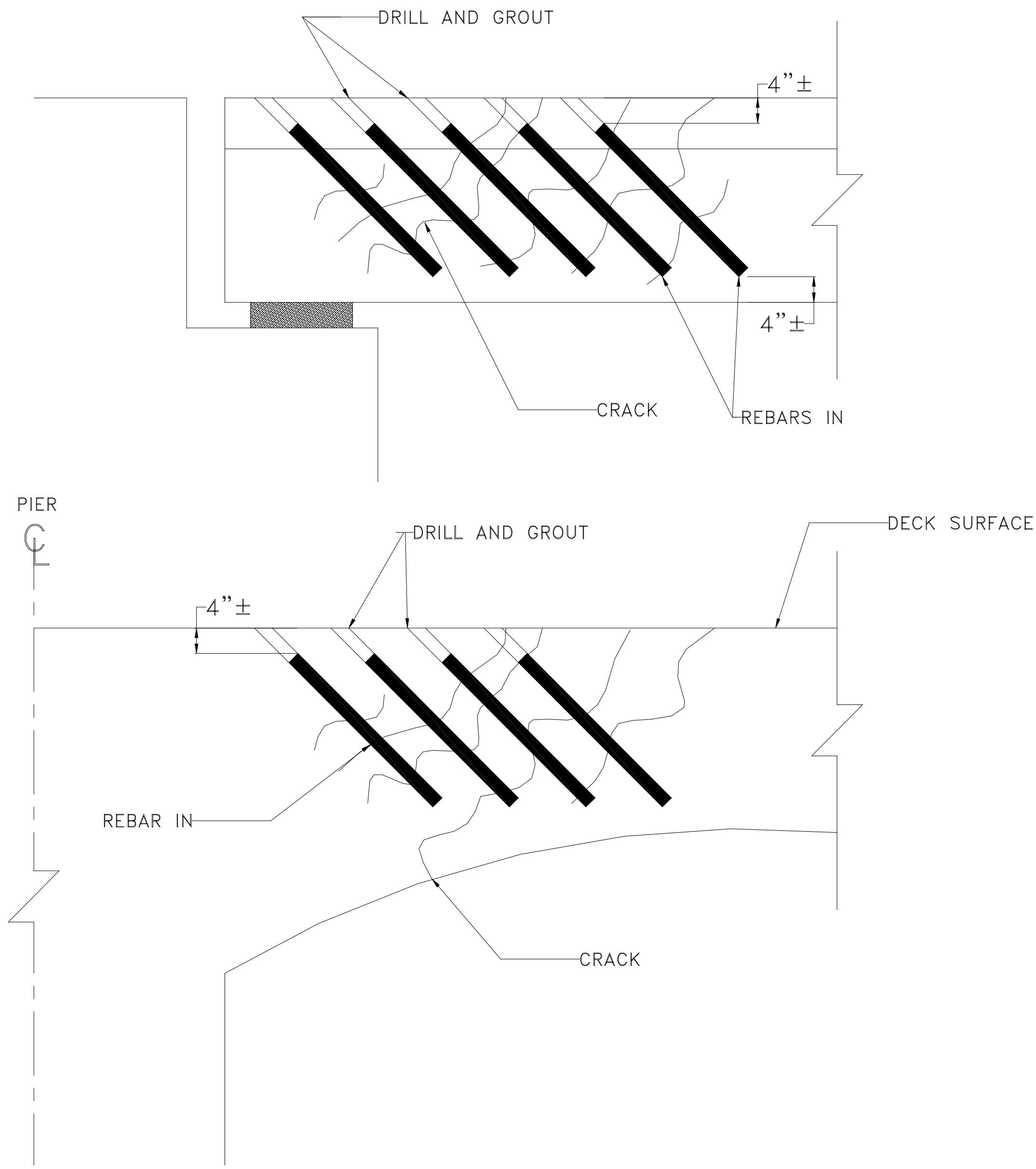


Figure 4-2
Repair of Shear Cracks in Center Web of Concrete Box Girder

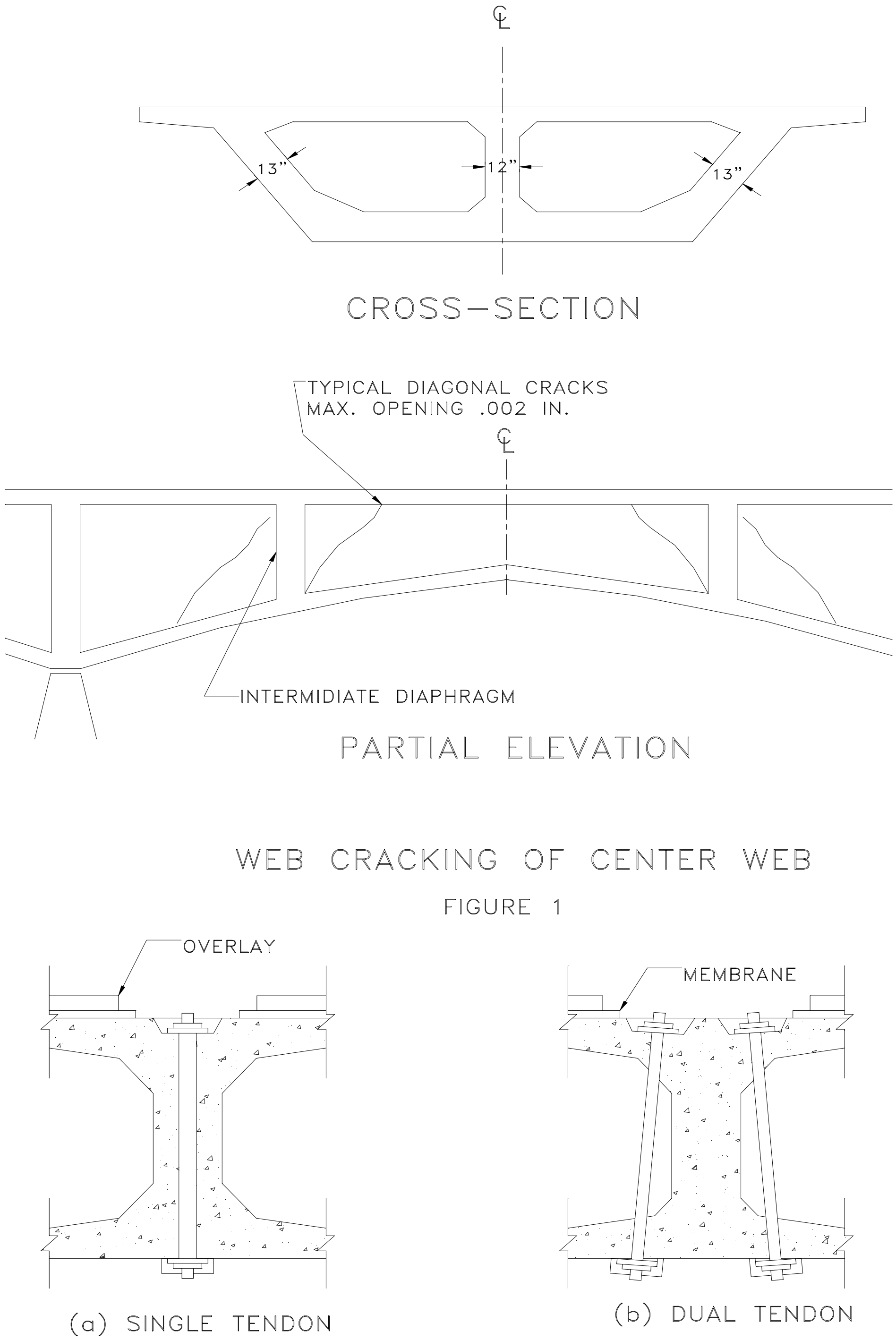


Figure 4-3
Repair of Shear Cracks In The Exterior Web of Concrete Box Girder

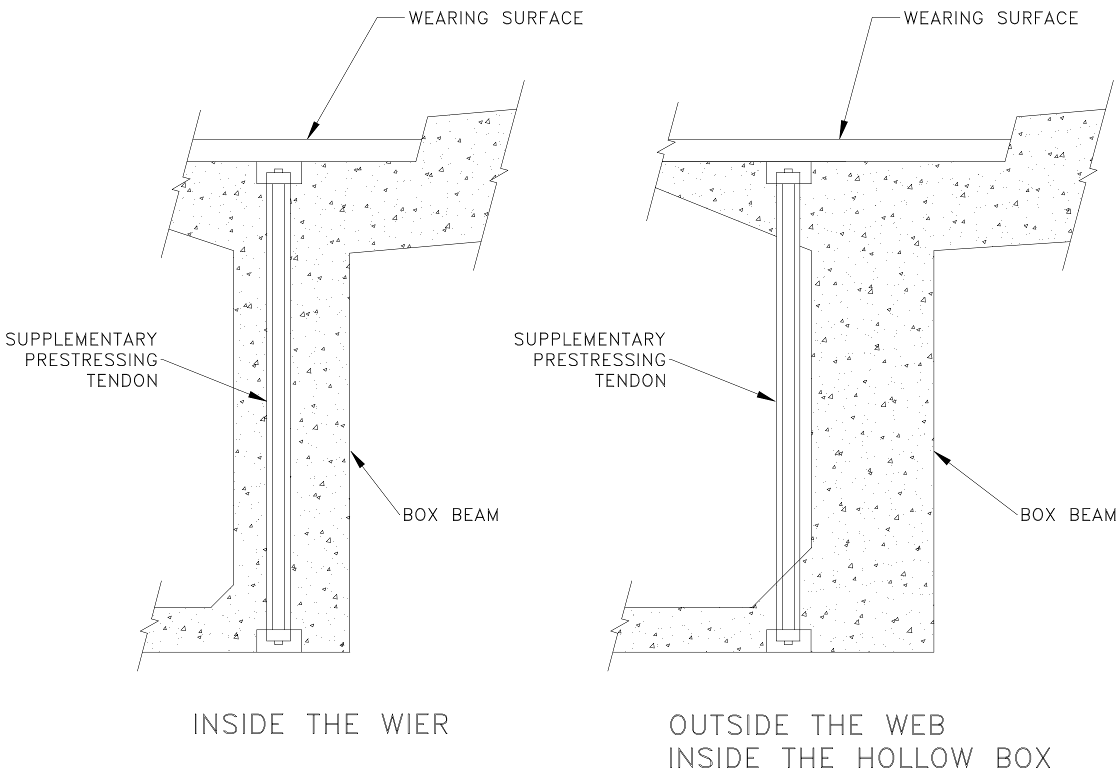


Figure 4-4
Repair of Shear Cracks In The Exterior Web of Concrete Box Girder

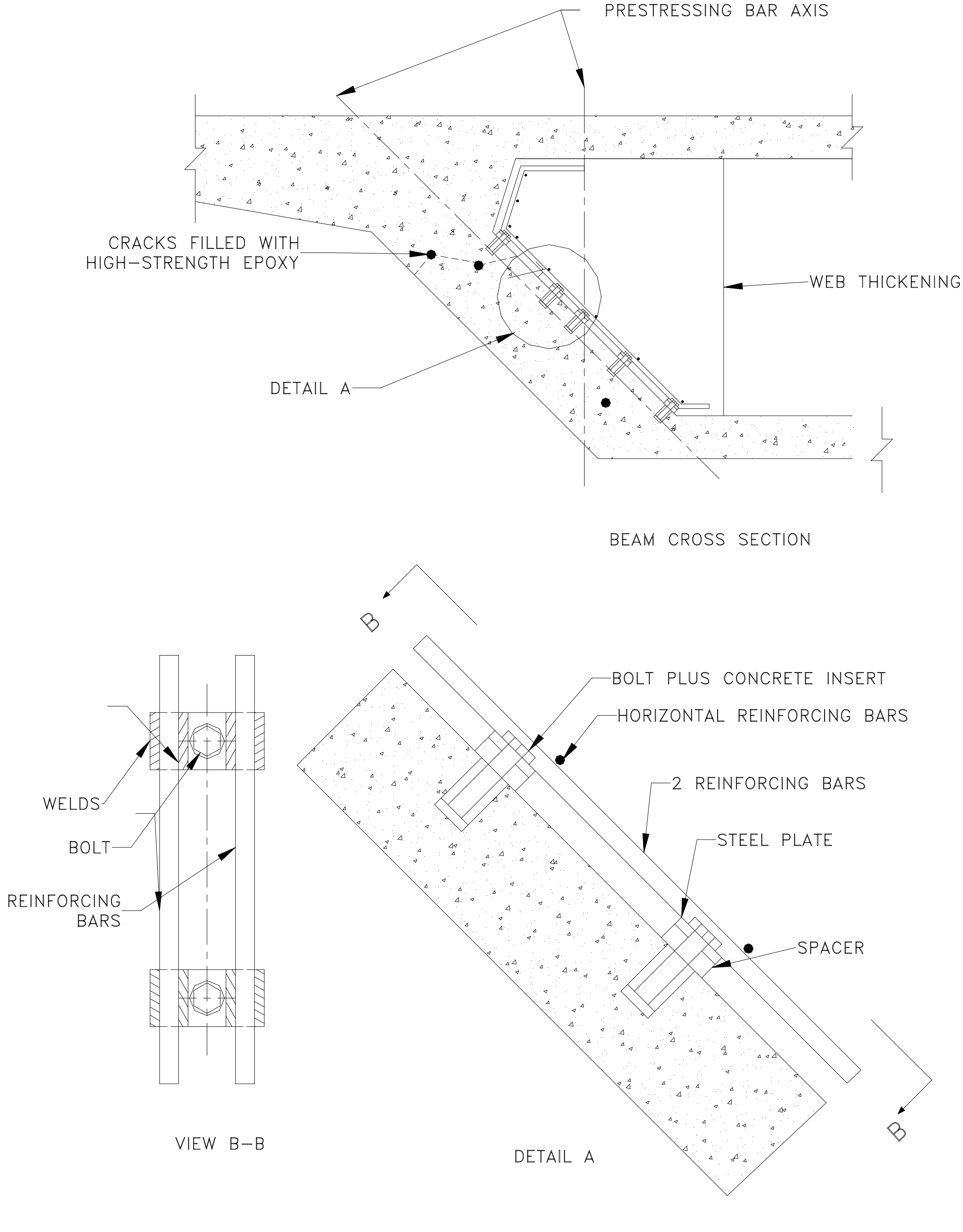
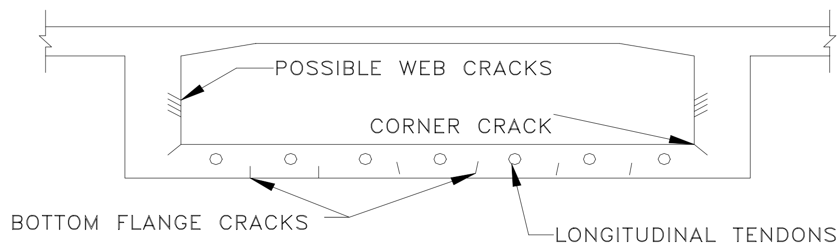
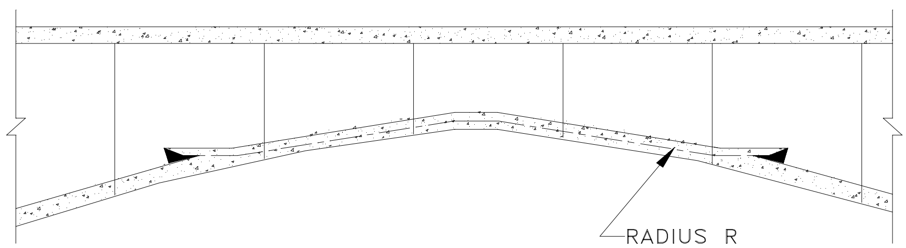


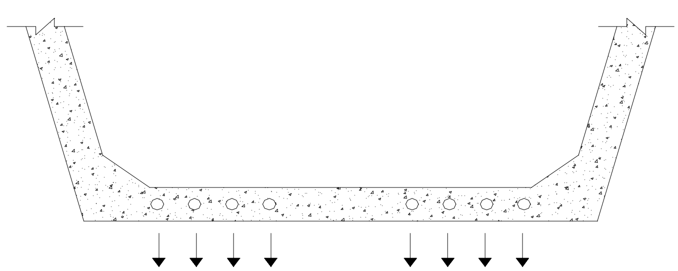
Figure 4-5
Repair Bottom Flange Cracks From Soffit Tendons In Concrete Box Girder



CRACKING FROM CURVED SOFFIT TENDONS

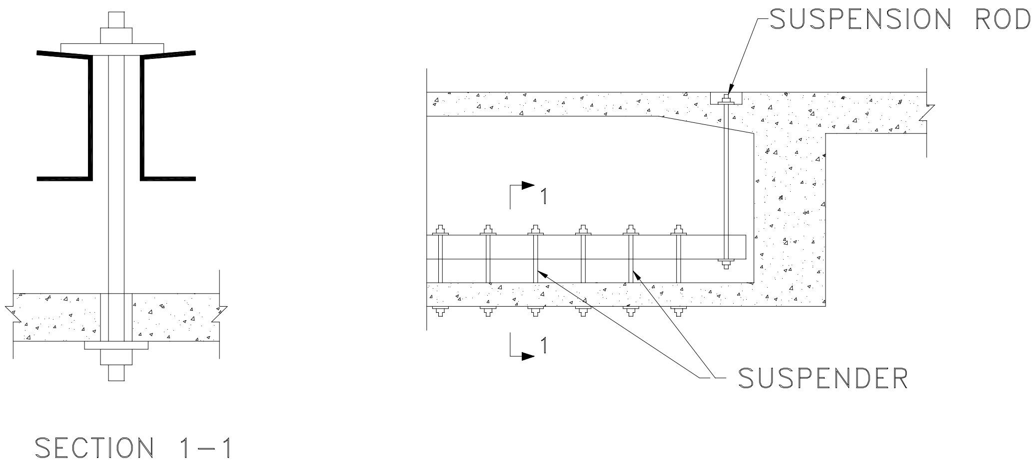


ELEVATION



PARTIAL CROSS–SECTION

Figure 4-6
Repair Bottom Flange Cracks From Curved Soffit Tendons In Concrete Box Girder



REPAIR SYSTEM
FIGURE 2

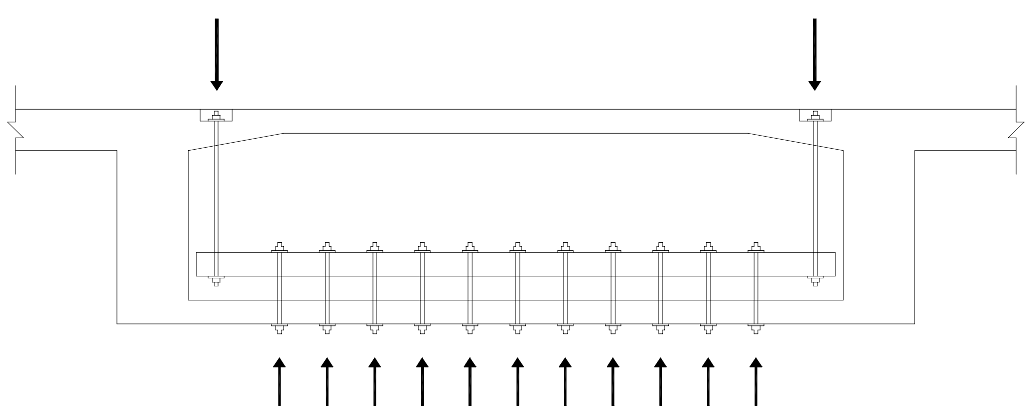


Figure 4-7
Detail of Repaired Beam End

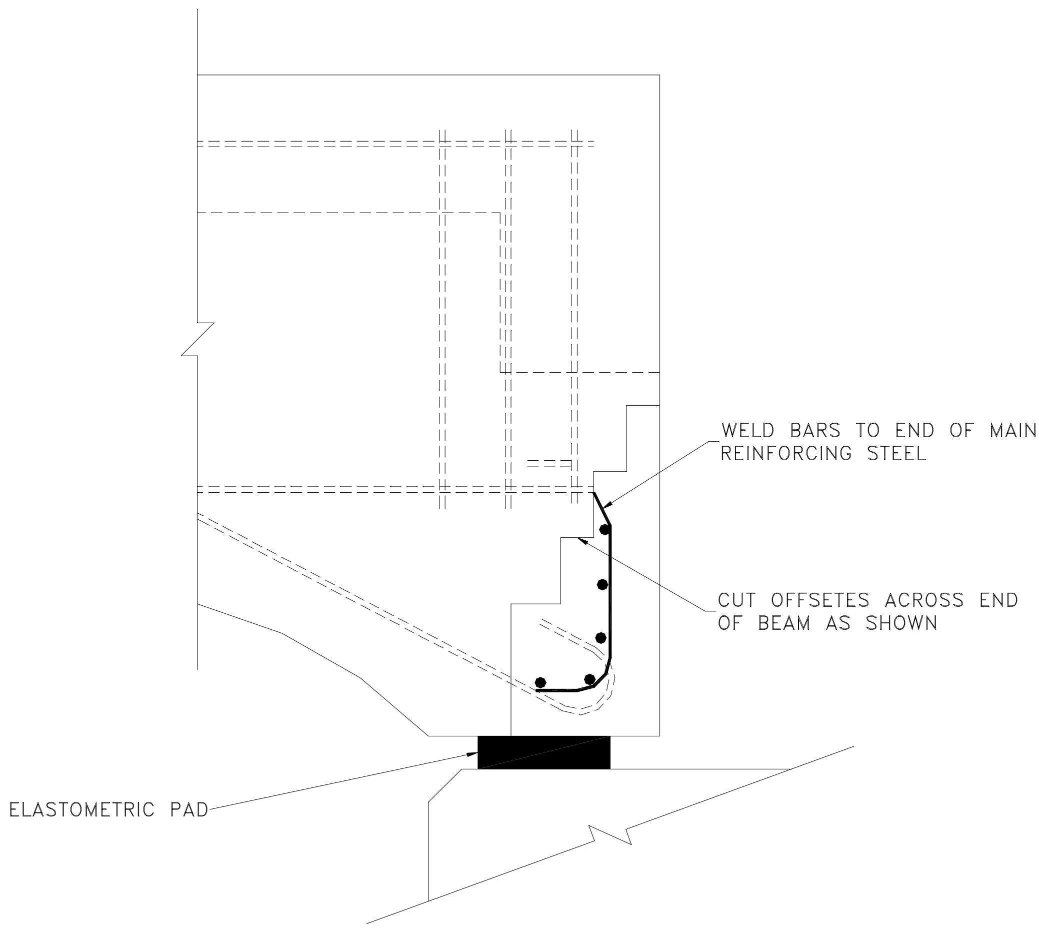


Figure 4-8
Repair of Broken Prestressing Strands

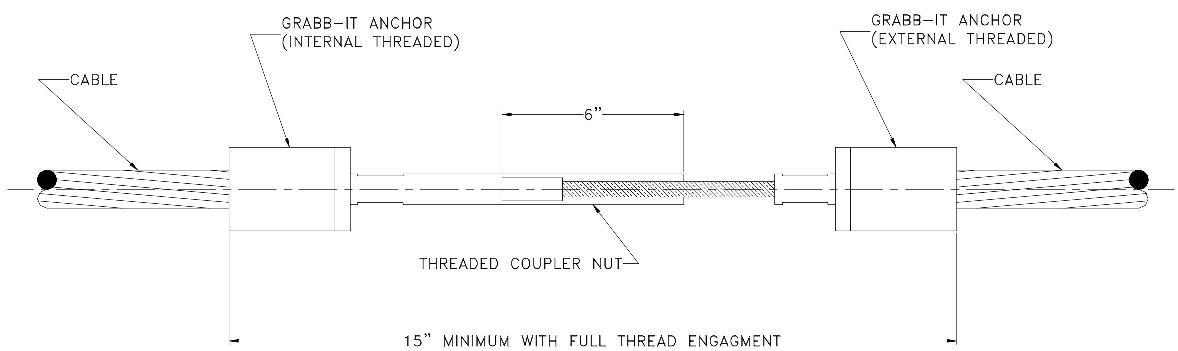


Figure 4-9
Corrosion Repair To Steel Beam

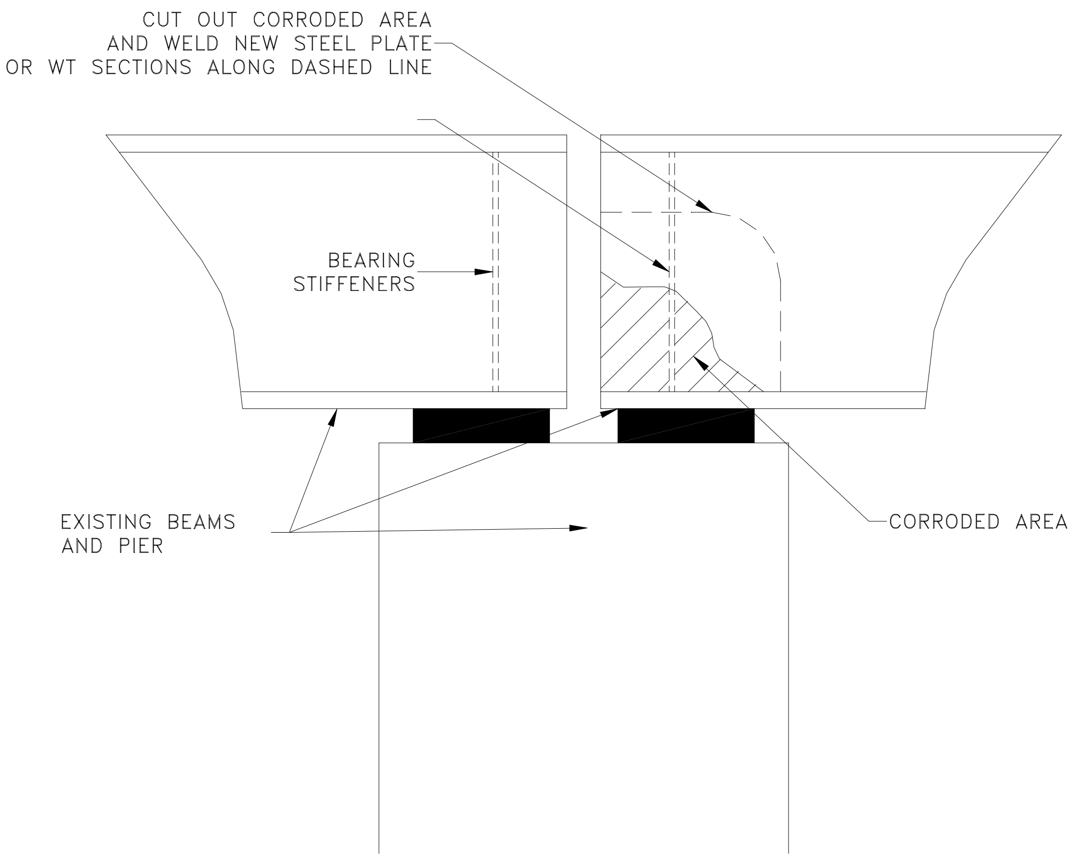


Figure 4-10
Strengthening Steel Beam By Post-Tensioning

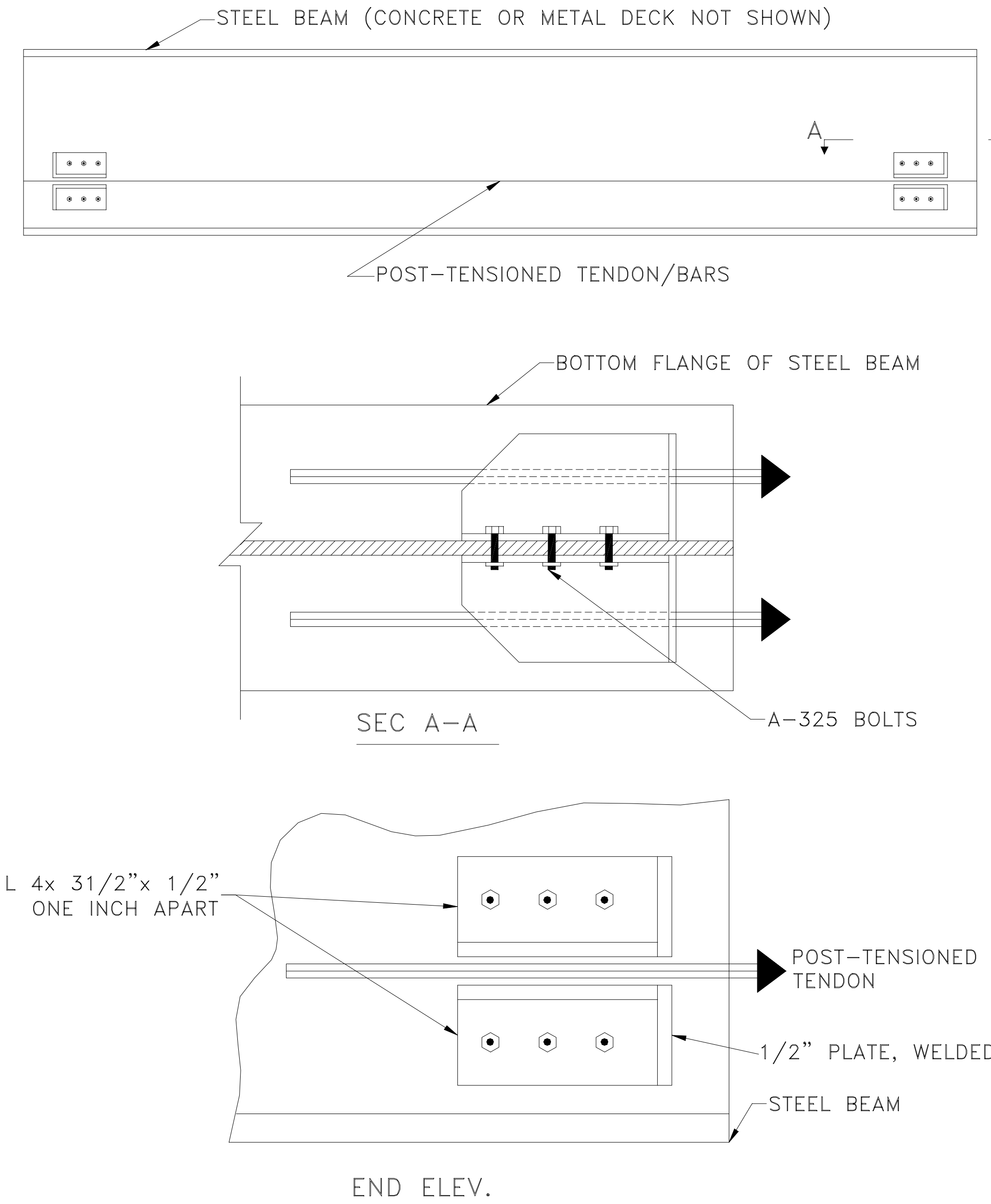


Figure 4-11
King Post Truss For Increasing Beam Capacity

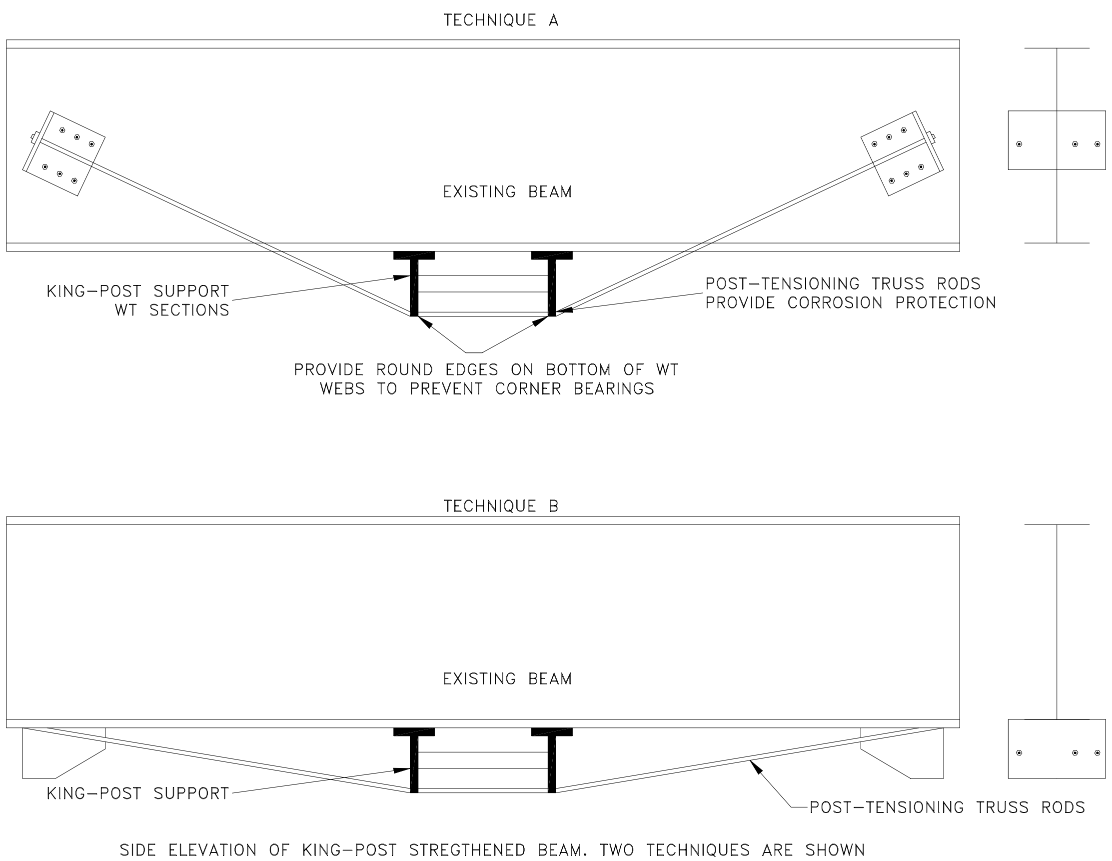


FIGURE 1

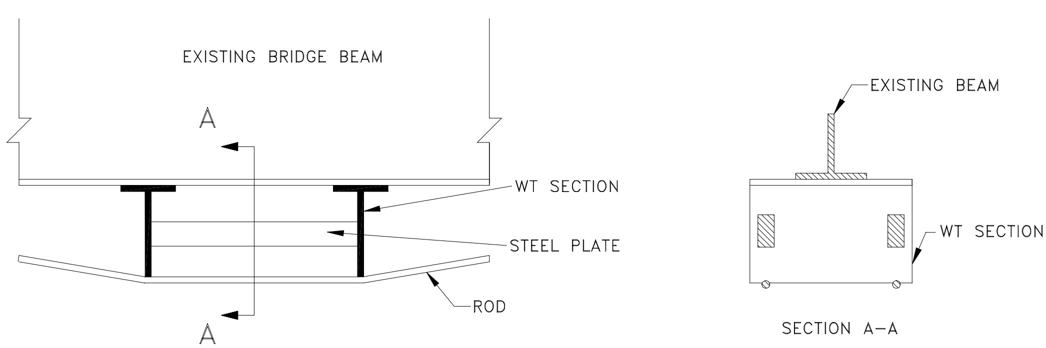
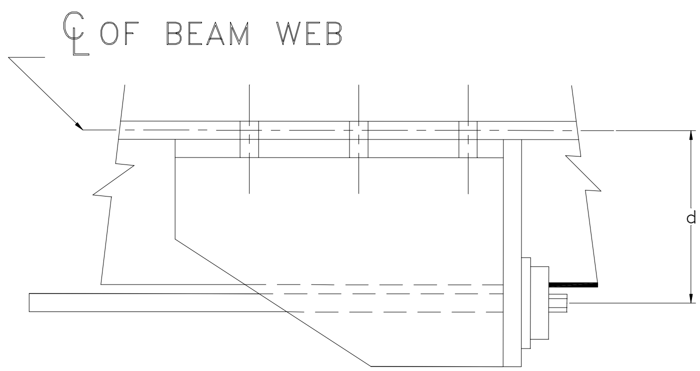


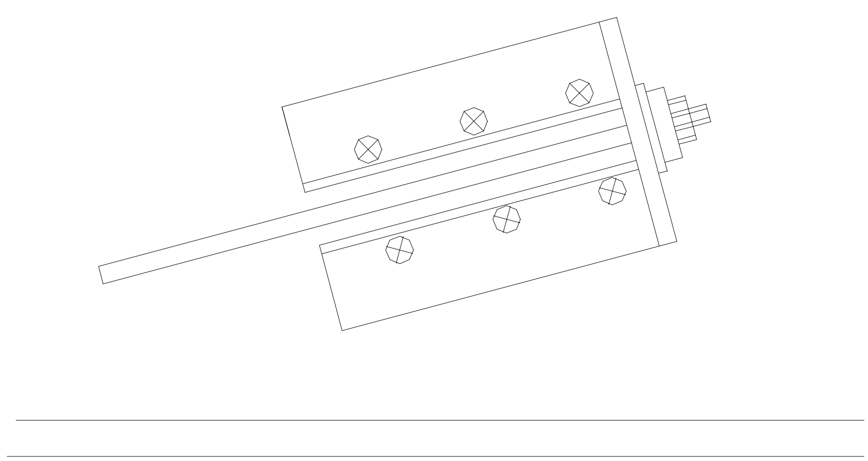
Figure 4-12
King Post Truss For Increasing Beam Capacity



PARTIAL PLAN

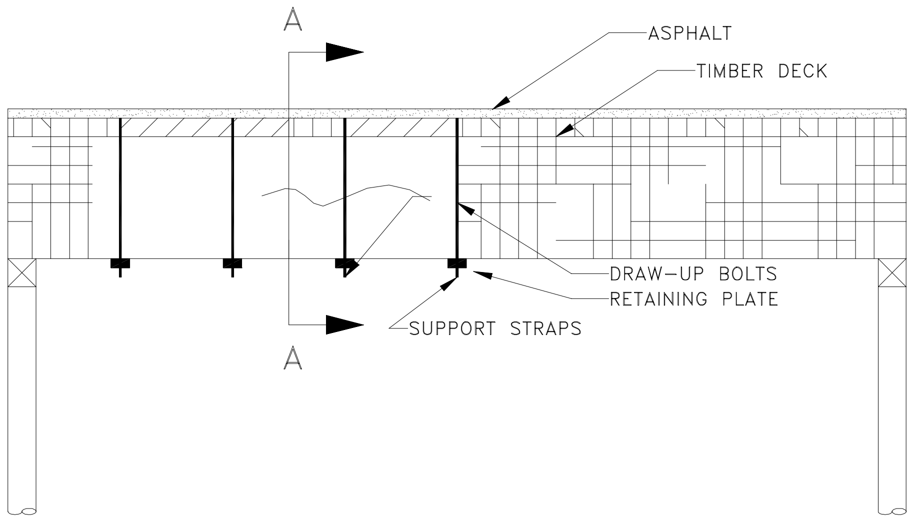
• –'d' SHOULD NOT EXCEED THE MINIMUM DISTANCE REQUIRED FOR THE TENSIONING RODS TO CLEAR THE FLANGE

NOTE: A BUILT UP SECTION MAY SOMETIMES BE REQUIRED



PARTIAL ELEVATION

Figure 4-13
Repair of Cracked or Split Timber Beam



SECTION A–A

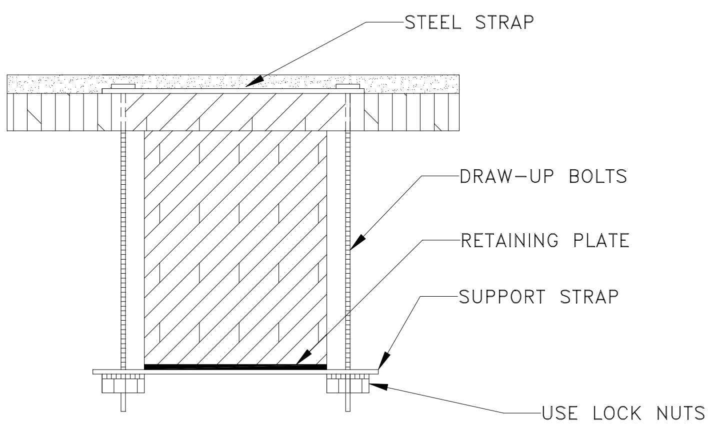


Figure 4-14
Timber Beam Replacement

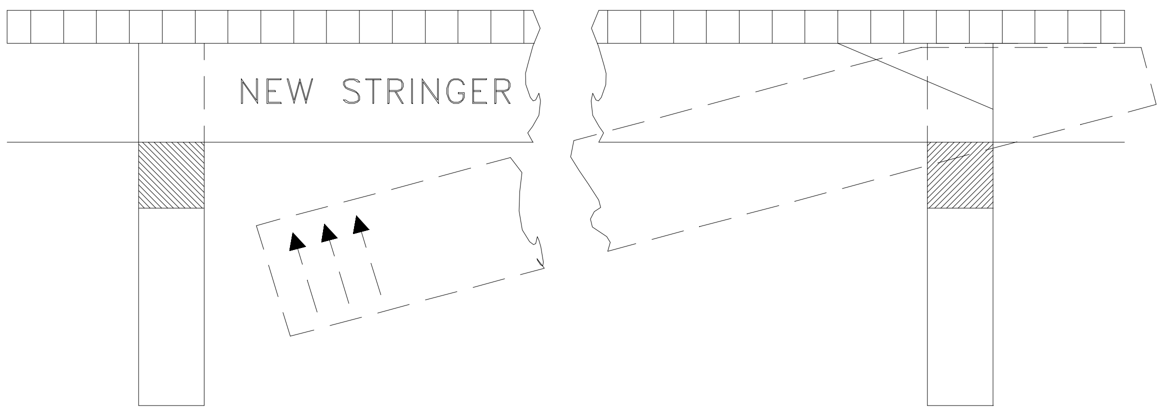


Figure 4-15
Temporary Support For Severely Damaged Exterior Concrete Beam

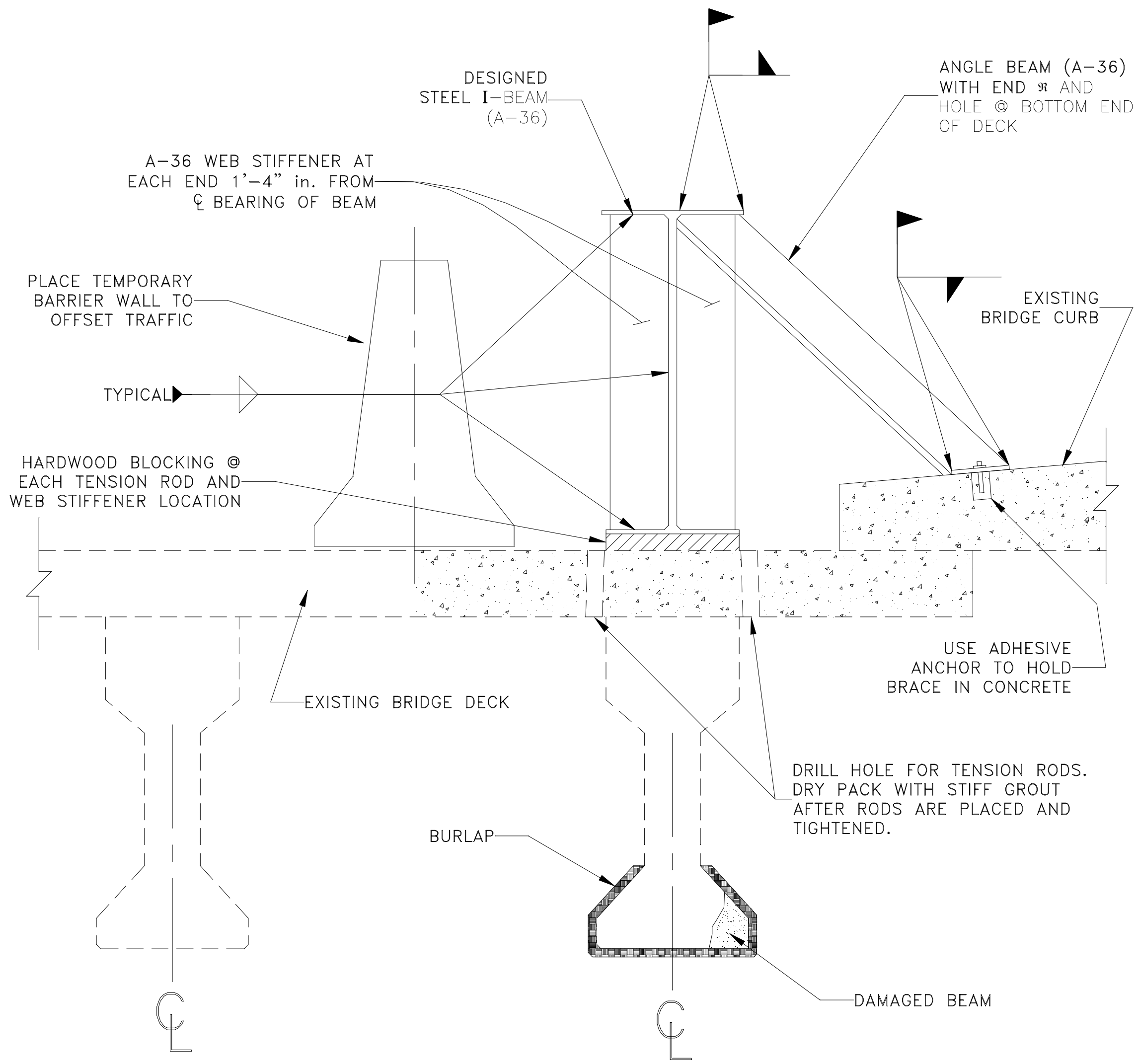


Figure 4-16
Temporary Support For Severely Damaged Exterior Concrete Beam

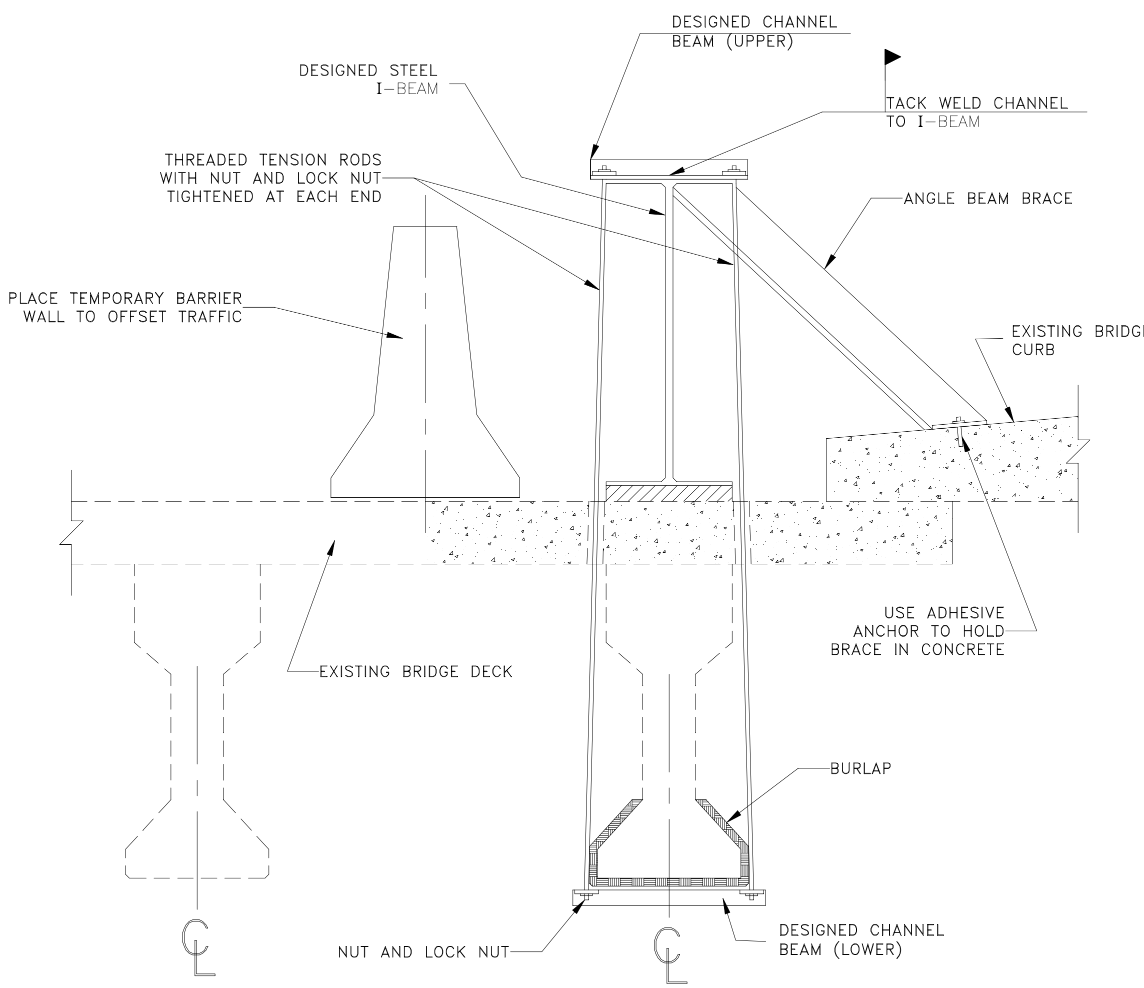


Figure 4-17
Temporary Support For Severely Damaged Exterior Concrete Beam

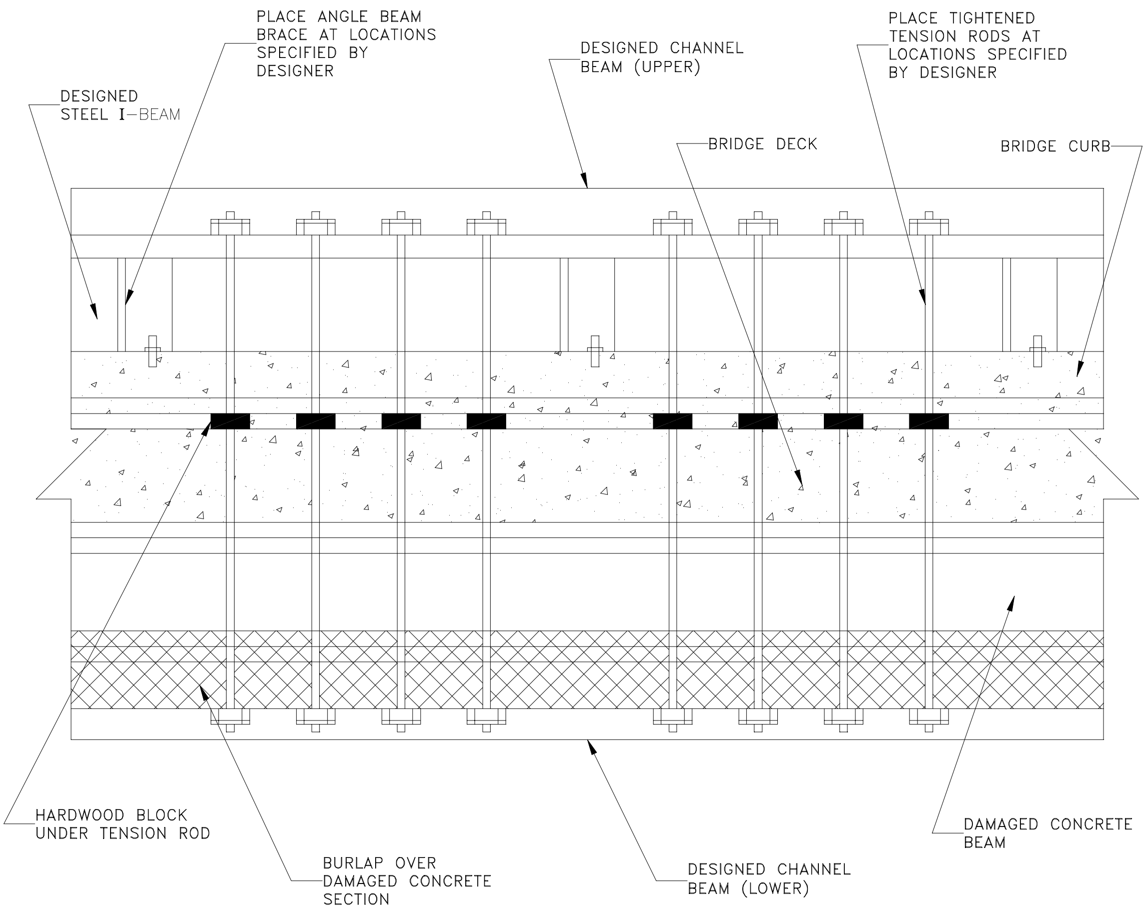


Figure 4-18
Truss Diagonal Replacement For Riveted or Bolted Connections

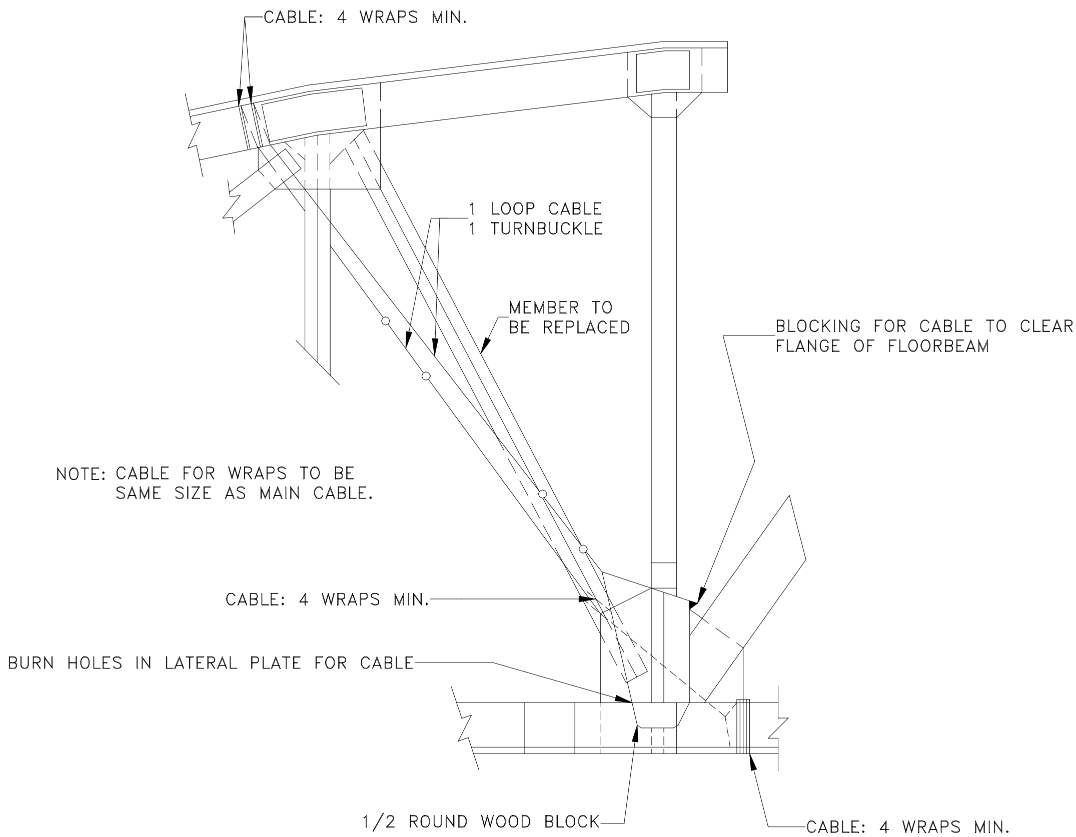
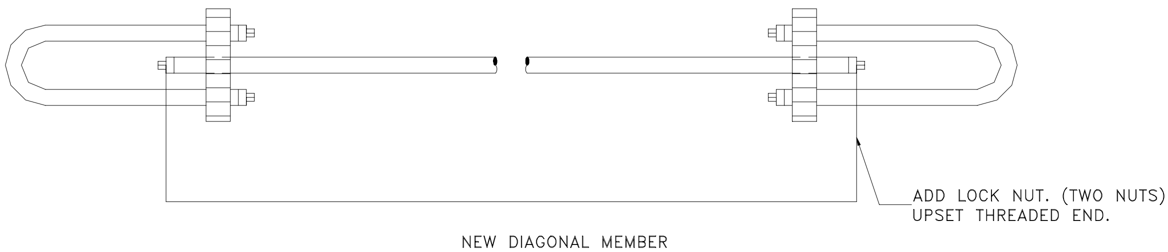


Figure 4-19
Truss Diagonal Replacement For Pinned End Connections



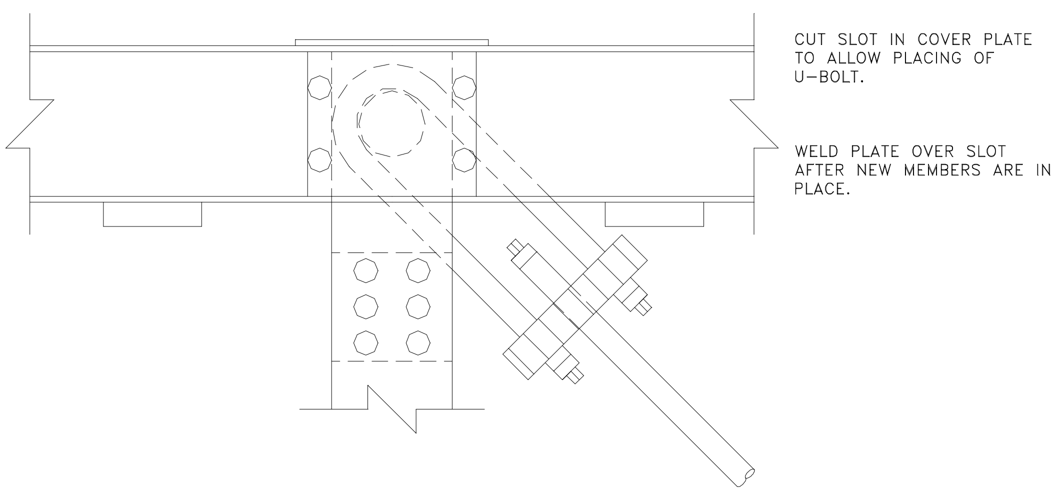
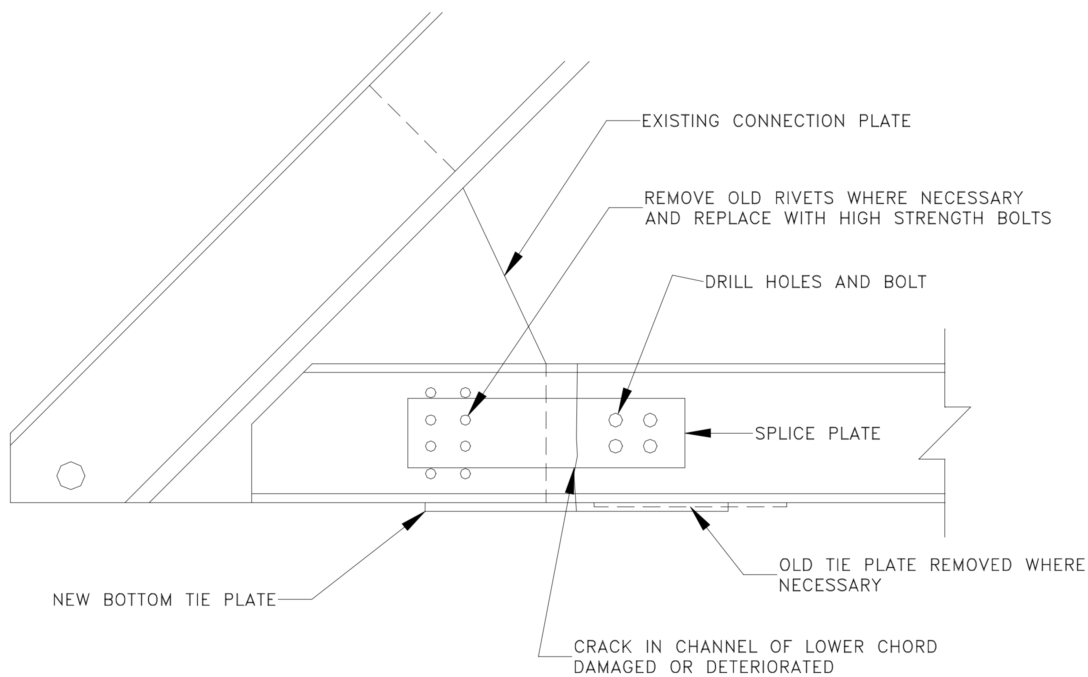


Figure 4-20
Typical Truss Repair
Where Complete Removal Is Not Necessary



CHAPTER 5

SUBSTRUCTURES

5.1 PREVENTIVE MAINTENANCE

Substructure problems include: deterioration (particularly at the water line), cracking (usually related to settlement), impact damage (associated with traffic under the bridge), and shear damage (associated with movement or approach pavement pressure). If the substructure is exposed to saltwater there are likely to be rebar corrosion problems. In addition to the problems listed above, timber substructures are damaged by decay and vermin attack.

Substructure repairs are often very costly, involving temporary bents to support the superstructure. Preventive maintenance is a cost-effective method of avoiding these costly repairs. Preventive maintenance includes removing debris and pressure-washing seats, caps and other surfaces exposed to salt.

5.1.1 Caps

Substructure caps of abutments, piers, and bents provide the seats or bases upon which bearing devices supporting the superstructure rest. Many bridges have open joints located over the caps, while some have drainage troughs to catch the drainage runoff. However, even with drainage troughs, the caps are commonly covered with dirt and debris. The accumulation of dirt and debris can hold moisture and chlorides against the cap, which can lead to deterioration of the cap and bearings. When the bearing system is frozen by corrosion, additional stress is introduced into the substructure cap, which can result in fracture of a concrete cap and loss of bearing area for the beam ends.

A routine substructure cap cleaning program is recommended. Cleaning the caps (and bearings) should be done as part of each routine bridge inspection. The use of a high pressure pump with adequate length of hose to flush off the substructure cap from every angle is an effective cleaning method. (The deck and expansion joint/troughs, as well as the deck drainage system should be done at the same time.) The caps do not receive the same type of rainwater flushing as the deck, expansion joints, and drainage system, and should be done routinely by the bridge inspectors or as part of routine maintenance.

The following preventive maintenance measures are also effective:

A. Drain Troughs

Installation of deck expansion joint drain troughs, if they can be accommodated, to protect the caps is a good preventive maintenance practice on bridges that do not already have them and which show evidence of cap deterioration caused by drainage, dirt and debris.

B. Surface Protection

Some states apply the protective coating to the bearing devices as well as to the substructure caps. Obviously this can only be effective if the protective coating is compatible with any paint system used on the bearings. When coating concrete caps, the best procedure is to extend the protective film on the abutments to a minimum of one foot below the bridge seat. On piers and bents, the extent of the coating may depend, to some extent, on appearance.

Surface protection of the concrete of the substructure caps should be applied using one of the types of protection described below:

1. Sealants

Impregnate the concrete, reduce its surface porosity and stabilize the outer layer. Types of sealant include Silane, Silicate, Siloxane, and High Molecular Weight Methacrylate (HMWM).

2. Coatings

Adhere to the concrete, seal the surface, fill small cracks, and provide some resistance to chloride attack. Types of coatings include Epoxy resins, hard urethane, and methacrylate.

3. Membranes

Fill cracks and provide maximum protection from chlorides. Membranes include elastomeric urethane, vinylester, and polyester.

5.1.2 Piles

Most piles require little maintenance because they are protected by the soil into which they are driven. Where piles are exposed, whether by design or by scour, there are potential problems. These problems include scaling and spalling of concrete piles, corrosion of steel piles and reinforced concrete piles, decay of timber piles, and buckling in all types if the unsupported length becomes excessive.

Preventive maintenance of exposed piles is the same as other substructure elements of the same material. For example, steel should be painted and concrete coated to protect against deterioration and corrosion. Timber piles are often used in bents to support small bridges. New cuts and bolt holes in treated timber should be thoroughly coated with preservative materials to prevent moisture from entering the wood and causing decay.

5.1.3 Cleaning

A. Recommended Method

Clean with shovel, brooms, high pressure water/air or mechanical devices:

1. Set up scaffolding or ladders or position man lift or snooper truck as required.
2. Flush all surfaces of piles, columns, and caps with high pressure water/air to remove dirt and debris.
3. Scrape, brush or chip all accumulated debris that cannot be removed by high pressure water/air flushing.
4. Cleaning operations under water are best accomplished using water jet equipment and hand tools.

5.1.4 Impact Damage

Guardrails and energy dissipaters can be installed to help protect against damage from highway traffic under the bridge. On navigable waterways, where ships or barges may contact piers and bents, adequate fenders are necessary to protect against damage. Steel plates can be installed on the upstream edge of a pier to reduce the damage caused by floating debris.

5.2 CATHODIC PROTECTION

5.2.1 Zinc Anodes - Small

Attachment, by use of a clamping device, of small zinc anodes to steel H-piles or reinforced concrete piles below water to abate corrosion of piles located in salt or brackish water when less than 8 lineal feet of pile is exposed. See Figures 5-1 and 5-2. These are applicable for all sizes of steel and concrete piles. The normal application consists of using 7 pound anodes. The use of 4 or 10 pound anodes requires additional site testing. Less brackish water or fast moving seawater will affect the two-year life expectancy requiring a change in the size of the anode. Contact the State Corrosion Engineer in Gainesville for coordinating design changes.

A. Steel H-Pile

1. Clean area on steel large enough to accommodate the clamp and hardware.
2. Place two anodes on each flange every 18 inches to the mud line. If the pile has concrete jackets in the splash zone, place the first two anodes 6 inches below the jacket in the water. See Figures 5-1 and 5-2

B. Reinforced Concrete Pile

1. Clean area on exposed reinforcing bar large enough to accommodate the clamp and hardware.
2. Place one anode on exposed reinforcing bar for each 6 lineal feet of pile in contact with brackish or salt water.

5.2.2 Zinc or Aluminum Anodes - Large

Attachment of large zinc anodes to steel H-piles below water by use of a clamping device to abate corrosion of steel H-piles located in salt or brackish water when more than 8 lineal feet of pile is exposed. See Figures 5-3 and 5-4. Applicable for 10, 12, and 14 inch piles. Zinc and aluminum anodes are comparable in efficiency, but both should never be used at the same site or installation.

A. Recommended Method

1. Anode should be placed approximately in the middle of the area to be protected. The top of the anode must always be below the low waterline.
2. Clean area on the steel pile large enough to accommodate the clamps.
3. Tighten the two clamps on the anode to the flange of the pile. Positive contact between the clamp bolt and the steel pile is absolutely essential.

5.3 PILE JACKETS

Jackets are the most common type of pile protection or repair. They are used for protection of all types of piles: concrete, steel, and timber. The jacket can be for protection from abrasion damage, for repair of section loss, or for both. If the jacket is for protection only, it could consist of a liner placed around the area to be protected with a cement or epoxy grout filler pumped into the space between the pile and the liner. If the jacket is intended to repair structural damage, the jacket will provide space for new reinforcement and the space between the liner and the old pile is filled with concrete. The liner is often a premolded fiberglass stay-in-place form; however, it could also be metal or fabric. Removable forms are also used, usually with reinforced concrete jackets.

In the proper environment, pile jackets can add years of service life to a bridge substructure. However, the use of concrete or epoxy grout filled fiberglass pile jackets to repair concrete bridge piles in a marine (saltwater) environment has resulted in several incidences of advanced corrosion conditions undetectable by the Department's bridge inspection personnel. On those bridges, many "good" pile jackets were removed for preventive maintenance, only to reveal that the pile had deteriorated so severely beneath the jacket that replacement of the pile was required. Contrary to popular belief, the jacket provides no protection system to arrest or reverse corrosive conditions, but instead provides a false sense of security for the future condition of the pile. Furthermore, the jacket liner prevents subsequent visual inspections of the original pile. Due to the possible deleterios effects mentioned above, future installation of pile jackets on marine piling is strongly discouraged. If pile jackets are used in a marine environment, they should incorporate a cathodic protection system.

5.3.1 Reinforced Concrete Pile Jacket

Concrete jackets can cause accelerated corrosion on a steel pile when both concrete and water are in contact with the steel. A corrosion cell will develop either below the bottom of the jacket or above the top of the jacket. Concrete jackets on steel piles should be extended well into the mudline and also, well above the waterline. For steel piles, strong consideration should be given to the installation of a sacrificial cathodic protection system in lieu of a pile jacket system.

Deteriorated reinforced concrete and prestressed concrete piles can be encased with a concrete jacket. Encasement will compensate for the cross-sectional area loss and strengthen the pile. Reinforcing steel cages or reinforcing wire are placed around the pile before the forms are placed. Stand-offs are placed on the reinforcement before they are drawn tight to the pile. Forms, either rigid or flexible, are then installed and sealed. Concrete is placed in the form either by tremie or pumping under water. After placing the concrete, the forms are removed when the concrete has cured. See Figure 5-5.

A. Recommended Method

1. Remove all cracked and unsound concrete.
2. Clean pile surfaces of oil, grease, dirt and other foreign materials which would prevent proper bonding. Water blasting is a quick and effective means of cleaning. Sandblasting and/or abrasion with powered rotary tools appear to create a better anchor profile.
3. Sandblast exposed reinforcing steel to "near-white metal".
4. Place reinforcing steel cage around pile.
5. Set forms for concrete jacket. (Treat forms with an approved form release agent before placing concrete.)
6. Dewater forms and place concrete.
7. Leave forms in place for a minimum of 72 hours.
8. Because the marine biofilms will begin to develop on submerged surfaces immediately after cleaning, which will cause the improper bonding, keep the time interval between surface preparation and concrete placement to an absolute minimum preferably less than 36 hours.

5.3.2 Fiberglass Pile Jackets

Fiberglass forms are used to construct pile jackets. Pile damage normally extends above and below the waterline, in the splash zone (Types 1,2,5, and 7 below) or at the mud-line (Types 3,4,6 and 8 below). The jackets can be installed on concrete and timber piles (Types 1-6 below) or steel H-piles (Types 7 and 8 below). The form has a vertical seam, so that it can be fitted around the pile. Subsequently, top and bottom centering devices and a bottom seal are installed. The form is secured in place with bolted bands and tightened to ensure full enclosure. As discussed in the introduction above, it is strongly recommended that future installations of pile jackets on marine piling incorporate cathodic protection systems.

A. Type 1-Epoxy Grout Filler w/Waterline Jacket

See Figure 5-6.

1. Clean pile surfaces of oil, grease, dirt and other foreign materials that would prevent proper bonding.
2. Remove cracked and unsound concrete or deteriorated wood.
3. Sandblast exposed reinforcing steel to "near-white metal". Splice with new reinforcement, if required.
4. Place pile jacket form around pile. Standoffs of either form material or concrete blocks should be permanently attached to form or pile.
5. Seal interlocking joint with bonding compound and seal bottom of form against pile surface.
6. Place external bracing and bonding materials.
7. Dewater form.
8. Fill annulus between the pile and form with specified filler.
9. Remove external bracing and banding, and clean any filler material deposited on forms.
10. Because the marine bio-films will begin to develop on submerged surfaces immediately after cleaning, which will cause improper bonding, try to keep the time interval between surface preparation and concrete placement to an absolute minimum, preferably 36 hours.

B. Type 2-Cement Filler w/Waterline Jacket

Refer to Type 1 procedure above. See Figure 5-7.

C. Type 3-Epoxy Filler w/Mud-Line Jacket

Refer to Type 1 procedure above. See Figure 5-8.

D. Type 4-Cement Filler w/Mud-Line Jacket

Refer to Type 1 procedure above. See Figure 5-9.

E. Type 5-RC Filler w/Waterline Jacket

Refer to Type 1 procedure above. See Figure 5-10.

F. Type 6-RC Filler w/Mud-Line Jacket

Refer to Type 1 procedure above. See Figure 5-11.

G. Type 7-Cement Filler w/Waterline Jacket on Steel H-Pile

Pile jacketing of steel piles is basically the same as that described previously for concrete or timber piles. Both flexible and rigid forms can be used. See Figure 5-12.

1. Clean pile surfaces of oil, grease, dirt and corrosion by sandblasting to "near-white metal".
2. Place pile jacket form around pile. Standoffs of form material should be permanently attached to form or pile.
3. Seal interlocking joint with bonding compound and seal bottom of form against pile surface.
4. Place external bracing and bonding materials.
5. Dewater form.
6. Fill annulus between the pile and form with Portland Cement filler.
7. Remove external bracing and banding, and clean any filler material deposited on forms.
8. Because the marine bio-films will begin to develop on submerged surfaces immediately after cleaning, which will cause improper bonding, try to keep the time interval between surface preparation and concrete placement to an absolute minimum, preferably 36 hours.

H. Type 8-Cement Filler w/Mud-Line Jacket on Steel H-Pile

Refer to Type 7 procedure above. See Figure 5-13.

5.3.3 Corrugated Metal Pipe Pile Jacket

Corrugated metal pipe can be used as a form for encasement of steel, concrete, or timber piles with a concrete jacket. The form is split and hinged to facilitate installation. See Figure 5-14.

A. Recommended Method

1. Remove all unsound concrete, steel corrosion, timber decay, marine growth, and other contaminants.
2. Place reinforcing steel as needed.
3. Size the corrugated metal pipe to allow proper cover around pile. Install handles on the outside of the forms. Set corrugated metal pipe split forms in place, working into ground line. Bolt or pin the split forms together.
4. Level, secure, and equal space form for equal cover around pile.
5. Dewater forms.
6. Place concrete.
7. Remove the forms to reuse, or leave the forms in place.

5.3.4 Fabric Pile Jacket

Encase deteriorated piles with fabric form and pump concrete into the form to restore the integrity of pile. This repair method can be used for the deteriorated timber, concrete or steel piles. See Figure 5-15.

A. Recommended Method

1. Clean the deteriorated piles of all marine growth and loose, cracked or unsound concrete by scraping or high-pressure water jet.
2. Place reinforcing bars, using spacers to maintain clearance between pile, reinforcing bars and fabric form.
3. The nylon fabric form is bolted to the top of the repair section with "U" straps made out of steel flat stock inserted into a hem in the top of the "Sea Form". The "Sea Form" is

zipped onto the pile and banded at the bottom to prevent the concrete from flowing out.

4. Insert the concrete hose into the form until the end is on the bottom of the form.
5. Pump the fresh water into the form to displace the saltwater. (The form has two sea cocks at the top, one for the pump hose and the other for the displaced water to exit.)
6. After saltwater is displaced, pump or tremie concrete into the form.
7. When the fabric form is full, the sea cocks are secured by wrapping them with tie wires.

5.3.5 Sacrificial Cathodic Protection Pile Jacket

This method is used to protect corrosion-damaged piles in a marine environment from further corrosion damage and to restore lost concrete cover. This method should be considered when the number of piles to be cathodically protected is small. A six-foot long fiberglass pile jacket containing an expanded zinc mesh anode around the concrete pile is installed. The expanded mesh is encapsulated inside the jacket using a sand-cement grout. A hull-type bulk zinc anode is also installed on the pile at a maximum elevation of 2 feet below low tide to cathodically protect the submerged portion of the pile. Sacrificial cathodic protection systems should be designed and/or approved by the FDOT Materials Office, Corrosion Research Laboratory in Gainesville. Inspection of system installation should be conducted in accordance with the design specifications to assure the system's proper performance.

A. Reinforced Concrete Piles

1. Clean pile surface of oil, grease, dirt, marine growth and other foreign materials that could prevent proper bonding between the old concrete and the new cement grout as per FDOT SPEC. PROVISION 457.
2. Locate center rebar on one face of pile using a pachometer and core-drill a 2 inch diameter access hole through the concrete to expose the steel. Drill and tap the rebar to accept a 5/16 inch stainless steel threaded rod for negative connection. After installation, the rod shall extend a minimum of 1 1/2 inches outside of the existing pile surface. Seal the core hole with sand-cement mortar.

3. Install fiberglass forms on the pile with bottom of forms positioned at low tide elevation and zinc band aligned with rebar negative connections. Seal forms and fill jacket with sand-cement grout as per FDOT SPEC. PROVISION 457. Fiberglass forms shall have the expanded zinc mesh and connection band attached prior to installation.
4. Install bulk anode on pile (using clamp brackets) at a maximum elevation of 2 feet below low tide. Secure anode wire to pile using stainless steel clamps and hardware.
5. Route zinc band and bulk anode wire to PVC connection box and connect to reinforcing steel through stainless steel threaded rod to provide a closed circuit system.
6. See Figure 5-16.

B. Prestressed Concrete Piles

1. Clean pile surface of oil, grease, dirt, marine growth and other foreign materials which could prevent proper bonding between the old concrete and the new cement grout as per FDOT SPEC. PROVISION 457.
2. Locate spiral tie on one face of the pile at an approximate elevation of 8 feet above low tide using a pachometer, then remove the concrete to expose the steel. Braze No. 8 AWG wire to the exposed tie and seal with epoxy after installation. An electrical continuity test of the reinforcing strands may be required prior to final system selection.
3. Install fiberglass forms on pile with the bottom of the forms positioned at low tide elevation and the zinc band aligned with the negative connection box. Seal forms and fill jacket with sand-cement grout as per FDOT SPEC. PROVISION 457. Fiberglass forms shall have the expanded zinc mesh and connection band attached prior to installation.
4. Install bulk anode on pile (using clamp brackets) at a maximum elevation of 2 feet below low tide. Secure anode wire to pile using stainless steel clamps and hardware.
5. Route zinc band and bulk anode wire to PVC connection box and connect to No. 10 AWG wire originating at the spiral tie.
6. See Figure 5-17.

5.3.6 Impressed Current Cathodic Protection Pile Jacket

This method is used to protect corrosion-deteriorated piles in a marine environment from further corrosion damage and to restore lost concrete cover to the reinforcement. This method is significantly more cost effective than the sacrificial method when numerous adjacent piles are affected and in need of cathodic protection. A 6 foot long fiberglass pile jacket containing a titanium wire mesh anode for DC current distribution around the concrete pile is installed. The titanium mesh is encapsulated inside the jacket using a sand-cement grout. A current rectifier and conduit system are installed to provide the cathodic protection current to the piles. Impressed current cathodic protection systems should be designed and/or approved by the FDOT Materials Office, Corrosion Research Laboratory in Gainesville. Inspection of system installation should be conducted in accordance with the design specifications to assure the system's proper performance.

A. Reinforced Concrete Piles

1. Clean pile surface of oil, grease, dirt, marine growth and other foreign materials that could prevent proper bonding between the old concrete and the new cement grout as per FDOT SPEC. PROVISION 457.
2. Locate center rebar on one face of pile using a pachometer and core-drill a 2 inch diameter access hole through the concrete to expose the steel. Drill and tap the rebar to accept a 5/16 inch stainless steel threaded rod for negative connection. After installation, the rod shall extend a minimum of 1 1/2 inches outside of the existing pile surface. Seal the core hole with sand-cement mortar.
3. Install fiberglass forms on the pile with bottom of forms positioned at low tide elevation and the titanium current distributor bar aligned with rebar negative connections. Seal forms and fill jacket with sand-cement grout as per FDOT SPEC. PROVISION 457. Fiberglass forms shall have the titanium wire mesh anode and current distributor bar attached to the inside of the forms prior to installation. The titanium distributor bar shall be welded to the mesh by resistance welding.
4. Install rectifier at a suitable location on the bridge. AC power needs to be provided to the rectifier if not available at this location. Connect the titanium bar to the positive terminal on the rectifier, and reinforcing steel (at the 5/16 inch stainless

steel rod) to the negative terminal using No. 10 AWG strand wire. Wires shall be routed from the piles to the rectifier in PVC conduit.

5. See Figure 5-18.

B. Prestressed Concrete Piles

1. Clean pile surface of oil, grease, dirt, marine growth and other foreign materials that could prevent proper bonding between the old concrete and the new cement grout as per FDOT SPEC. PROVISION 457.
2. Locate spiral tie on one face of the pile at an approximate elevation of 8 feet above low tide using a pachometer, then remove the concrete to expose the steel. Braze No. 8 AWG wire to the exposed tie and seal connection with epoxy after completed. Route wire to PVC negative connection box on the concrete surface and seal with sand-cement mortar. A minimum of 1 inch of wire shall be brazed to the steel tie. An electrical continuity test of the reinforcing strands may be required prior to final system selection.
3. Install fiberglass forms on the pile with bottom of forms positioned at low tide elevation and the titanium current distributor bar aligned with rebar negative connections. Seal forms and fill jacket with sand-cement grout as per FDOT SPEC. PROVISION 457. Fiberglass forms shall have the titanium wire mesh anode and current distributor bar attached to the inside of the forms prior to installation. The titanium distributor bar shall be welded to the mesh by resistance welding.
4. Install rectifier at a suitable location on the bridge. AC power needs to be provided to the rectifier if not available at this location. Connect the titanium bar to the positive terminal on the rectifier, and reinforcing strands (at No. 8 copper strand wire) to the negative terminal using copper strand wire. Wires shall be routed from the piles to the rectifier in PVC conduit.
5. See Figure 5-19.

5.4 CONCRETE PILE REPAIRS

Deteriorated concrete in a concrete pile should be removed to sound concrete. The reinforcing steel should then be cleaned of all rust and scale, and the concrete replaced. Sufficient concrete should be removed so that new concrete is placed to a minimum of 2 inches in depth. After forms are placed, all old concrete surfaces that will contact the new concrete should be covered with a bonding material. The new concrete is then placed or grout injected (dry packed aggregate may be used).

5.5 CONCRETE CAP REPAIRS

Problems often found in concrete bridge seats include the deterioration of concrete and the corrosion of reinforcing bars. Such problems are caused by moisture and contaminants falling through leaking deck joints. A horizontal crack along the face of the pier cap, 3 to 4 inches from the top, normally indicates that the top mat of rebars has expanded because of corrosion and has forced up (delaminated) the concrete.

5.5.1 Repair Of Sheared Concrete Beam Seat

When a superstructure moves beyond the space that is provided for it in the bearing devices, pressure is created on the anchor bolts. This can be caused by an inadequate design, improper placement of the bearings, movement of the superstructure, or corrosion-producing friction between the sliding surfaces. Lateral force, such as large debris striking a bridge during periods of high water or an over-height vehicle hitting a beam, can also create large forces on the anchor bolts. The pressure from the anchor bolts is then transmitted to the substructure cap, which can cause damage to the bridge seats or cracks in other parts of the substructure, such as the columns.

On some older concrete bridges, no bearing device was provided except for a thin fabric or tar paper bond breaker. Friction created by the beam or bearing device sliding directly on the bridge seat can cause the edge of the seat to shear. Insufficient reinforcement can contribute to this problem.

During the planning stage, necessary substructure repair procedures should be determined. These procedures should then be scheduled in a logical order, and they may include the following:

- Identification of damaged area by sounding and marking the unsound concrete.
- Make provisions to correct the cause of damage.
- Plan to remove traffic from the bridge during jacking.

- Determine the size, number and location of jacks that are required.
- Ensure that jacking will not damage joints, bearings, or area supporting the jacks.

Reconstruction of a substructure cap requires raising the superstructure in order to provide work space, as well as to take the load off the cap. If traffic is allowed on bridge during the jacking operations, vehicle live loads must be included in the jacking loads. A registered engineer shall approve the complete repair procedure.

A. Recommended Method

1. Construct a temporary bent for supporting jacks and blocking if jacking from abutment or pier elements cannot be accomplished.
2. Restrict traffic from the bridge while jacking the superstructure.
3. Lift jacks in unison to prevent a concentration of stress in one area and possible damage to the superstructure.
4. If the bridge will carry traffic during repairs, restrict vehicles away from repair area as much as possible.
5. Saw cut around concrete to be removed and avoid cutting reinforcement.
6. Remove deteriorated concrete to horizontal and vertical planes using pneumatic breakers.
7. Add new reinforcing steel where required.
8. Apply bonding material to prepared surface that will interface with new concrete.
9. Form as required and place new concrete.
10. Service, repair and replace bearings as necessary.
11. After concrete has reached required strength, remove forming, blocking, jacks, and temporary supports.
12. See Figure 5-20.

5.5.2 Temporary Steel Frame Support For Repair Of Cap

A temporary steel frame support can be used during the repair of pile caps. The frame is placed to transmit the superstructure dead load to the piles while the deteriorated concrete is removed from the cap. See Figures 5-21, 5-22A, and 5-22B.

A. Recommended Method

1. Drill holes transversely throughout piles. Avoid damaging the pile reinforcement.
2. Install bars and steel channels to form a frame around pile.
3. Erect connecting columns and steel channels.
4. Drill holes longitudinally throughout the pile cap and install steel bars.
5. Assemble the support frame using steel bars and high strength bolts, which shall be tightened to a snug tight fit.
6. Frame shall not be removed until the new concrete has reached the required strength.
7. Holes in piles and pile cap shall be filled with non-shrinking grout after removal of steel bars.

5.6 STEEL PILE REPAIRS

Steel H-piles may be damaged, particularly if located in waterways where they may be struck by heavy barges or, infrequently, near roadways as in work zones where they may be struck by heavy construction equipment. Damage in the form of bent, torn or cut flanges may effectively reduce the cross section and load-bearing capacity so that a repair must be performed. More commonly, steel H-piles may become severely corroded in a relatively short section near the main waterline in a waterway or as the result of unusual conditions such as broken drains. A steel H-pile that is otherwise sound, cannot be easily replaced or supplemented because of access or scheduling, may be strengthened by repairing with bolted channels as a temporary measure. See Figure 5-23.

A. Recommended Method

1. Clean damaged pile.
2. Locate extreme limits of deteriorated section. Channel section shall be 18 inches longer than the distance between those limits.
3. Thoroughly clean area to which channel is to be bolted.
4. Clamp channel section in place against pile.
5. Locate and drill holes through channel and pile for high strength bolts. If the holes are pre-drilled in the channel, the channel may make a good template for drilling the pile.
6. Place bolts and secure.
7. Remove clamps.

8. If pile repair is above water, coat with protective coating. If under water, protect with zinc anodes.

5.7 TIMBER PILE REPAIRS

5.7.1 Timber Pile Replacement

Drive treated timber pile through deck and fasten in place under cap. Use this method to replace a deteriorated timber pile where conditions for splicing are not practical. The District Bridge Engineer shall design the detail of this method. The District Bridge Engineer shall approve the jacking method. Use bolts to connect straps to pile and cap.

A. Recommended Method

1. If deck is overlaid with asphalt or concrete, locate centerline of beams closest to pile replacement.
2. Cut through overlay and timber deck along centerline of beam. Remove sufficient number of timber decking pieces to permit pile to go through hole adjacent to cap. If deck is not overlaid, cut timber decking at centerline of beam near centerline of bridge and remove decking across travel lane.
3. Remove cross bracing from between the piles and on the side of the bent where new pile will be driven.
4. Set pile at slight batter so when driven and pulled under cap, it will be plumb. Drive to specified bearing.
5. Install U-clamps and supporting frames and blocking around pile to be replaced. Place jack on blocking and jack cap up approximately 1/2 inch.
6. Cut pile 1/4 inch below cap and pull pile into position under cap. Positioning pile can be accomplished by using come-alongs to pull against adjacent bents. Place copper sheeting on pile head.
7. Lower jack and strap in place.
8. Reconstruct cross bracing on bent piles.
9. Replace timber decking and overlay with asphalt or concrete if deck is overlaid.

5.7.2 Timber Pile Splice

Partial replacement of deteriorated pile with new section of treated timber pile. Used for repairing timber piles that are deteriorated at the ground line or above.

No more than 50 percent of the piles in a bent should be repaired with this method.

A. Recommended Method

1. Remove soil around pile to depth well below permanent moisture.
2. Construct cribbing or place struts for supporting jacks.
3. Place jacks and lift cap 1/2 to 1 inch.
4. Cut steel dowel connecting cap and pile with torch or hacksaw.
5. Cut deteriorated pile off below permanent moisture line. Make cut at right angle to centerline of pile.
6. Cut new pile section 1/4 inch longer than removed section.
7. Place new pile section on pile stump and under cap at same location as original pile. Make sure there is even contract at bearing points. (Top of stump and bottom of cap.) Place copper sheet on pile head. Lower jacks.
8. Place form and reinforcing steel for concrete jackets.
9. Pour concrete (Class II) minimum of 6 inch cover around pile. (Top of jacket should be sloped slightly to allow water to run off.)
10. Drill holes and attach steel plate to pile and cap as shown in details. Strap cap and pile together with bolts through timber and secure with nuts.
11. The District Bridge Engineer shall approve the jacking method.

5.7.3 Timber Pile Sway Bracing

Erecting timber sway bracing on existing pile bent or cutting and replacing sections of existing sway bracing. When scour affects the lateral stability of a pile bent where sway bracing was not originally specified, erect new sway bracing. Also where original sway bracing has deteriorated, replace in whole or part as necessary.

A. Pile Bents Without Sway Bracing

When sway bracing is deemed necessary by the engineer, measurements should be taken and timber cut to dimension before treatment.

1. Temporarily attach sway bracing to piling in its final position with galvanized nails. Nails should be driven so as not to interfere with bolt installation.
2. Locate bolt holes and drill through bracing and pile. Use same diameter drill bit as bolt diameter.
3. Treat all holes with hot oil preservative before installing bolts.
4. Place bolts, washers and nuts, then tighten.
5. Some bents may require horizontal bracing at bottom of sway bracing. Use same bolt hole on exterior piles for this bracing as for sway brace members.

B. Repair of Existing Sway Bracing

1. Locate end of deteriorated or damaged section of sway brace. Cut off brace at the next pile.
2. Measure length of new bracing required to re-connect piles and cut new sections.
3. Re-bolt through existing holes in pile where possible. Drill new holes in piling when new sway brace must be realigned. Treat both new bolt holes and old ones to be reused with hot oil preservative.
4. Treat all timber cuts, both old and new sway bracing, with hot oil preservatives followed by a coating of hot tar.

5.7.4 Shimming Timber Piles

This procedure involves placement of a steel wedge between cap and pile head. Use to restore bearing that has been lost between the pile cap and pile due to settlement. Also may be used when top few inches of pile is decayed.

A. Recommended Method

1. Place cribbing or strut adjacent to pile to be shimmed. If several piles in one bent need shimming, cribbing should be placed to allow shimming all piles at one time.
2. Set jacks on cribbing (strut) and raise approximately 1/2 inch higher than desired elevation.
3. Use steel shim 1/4 inch less than opening between cap and pile head, then place the shim into position.
4. Lower jacks and toenail shim to pile.
5. Remove cribbing.

5.7.5 Replacement of Damaged or Decayed Timber Piles

Partial replacement of damaged or decayed timber piles with new section of treated timber piles. This method is used for repairing timber piles that are deteriorated at the mud line or above. No more than 50 percent of the piles in a bent should be repaired with this method. The District Bridge Engineer shall design the detail of the method. The District Bridge Engineer shall approve the jacking method. Qualified personnel will handle the jacking operation.

A. Recommended Method

1. Move traffic from side of bridge being repaired.
2. Remove cross bracing as necessary to install new pile.
3. Place the jacking beam on timber blocks above the area to be supported. See Figure 5-24.
4. Drill holes through the deck to accommodate the rods for the support bracket taking care not to damage existing reinforcing steel. See Figure 5-25.
5. Install the support bracket.
6. Place the jack under the end of the jacking beam and raise the superstructure to the required clearance.
7. Shim blocks to support the jacking beam.
8. Remove deteriorated portion of existing pile cutting end off level.
9. Install new treated timber pile and pile splice sleeve.
10. Reinstall cross bracing. See Figure 5-26.
11. Lower the superstructure onto its permanent support and remove the jacking beam.
12. Repair the holes made in the deck for the support rods.
13. Restore traffic.

5.8 TIMBER CAP REPAIRS

5.8.1 Timber Cap Replacement

Remove load from existing timber cap, remove cap and replace with new timber cap. Use to replace deteriorated timber cap at an intermediate pile bent or end bent. Two different methods may be employed for removing load from existing cap: (1) jacking from cribbing, and (2) jacking from the pile bent itself. See Figure 5-27.

Cribbing can be used to jack from end bent or intermediate bent caps. For end bent caps, place cribbing in front of bent leaving room for removal and replacement of cap. For intermediate bents, place cribbing on both sides of bent. Place jacks on cribbing. For timber spans, use false caps to jack against the beam bottom. On spans with steel beams, jack against the bottom flange of the beams.

Jacking from the pile bent itself is used only on intermediate bents for timber structures or steel beam spans where beams are continuous over the intermediate bent. Place two U-clamps and supporting frames and blocking on each pile in the bent. Hang 6 inch X 12 inch timber above blocking and place jacks.

A. Recommended Method (for either method)

1. Hang new cap alongside of existing cap.
2. Jack up span 1 to 2 inches.
3. Cut dowels connecting piles and cap with burning torch or hacksaw.
4. Slide old cap off piling and move treated new cap into position.
5. Lower jacks.
6. Connect cap to piles with steel straps and spikes.
7. Remove cribbing or jacks and U-clamp rigging.

5.8.2 Timber Cap Scabs

Attach 6 inch X 12 inch treated timber scabs on each side of an existing timber cap using split-ring connectors and bolts. Apply to caps to extend bearing area where bottoms of stringers or laminated decking have deteriorated over existing cap. Existing cap must be sound timber.

A. Recommended Method

1. Locate work platform or work barge as needed.
2. Use template to layout split-ring locations on cap and timber scabs.
3. Cut split-rings and drill bolt holes.
4. Insert split-rings in cap.
5. Raise scabs into position and clamp to cap or use bolts to temporarily hold in position.

6. Place O.G. washers and nuts on one end of bolts, then insert bolts in pre-drilled holes.
7. Place O.G. washers on opposite end of bolts and tighten to final fit.

5.8.3 Strengthen Existing Cap

Strengthen the existing cap by notching the pile and clamping new members on the pile cap. This method can be used to strengthen the cap by enlarging the bearing area. See Figure 5-28.

A. Recommended Method

1. Notch existing pile if necessary.
2. Clamp new members as shown.
3. Drill bolt holes and treat with preservative.
4. Place bolts and tighten.

5.9 HELPER BENT INSTALLATION

5.9.1 Addition of Supplemental Piles

Strengthening of weak or settled pile bent through use of supplementary steel H-piles and steel beam sub-caps. Traffic must be restricted to one lane or bridge closed to traffic as necessary. Piles are driven through holes in the deck. The bridge must be able to support the weight of pile driving equipment. Dry land or floating pile-driving rig could be used. The District Bridge Engineer shall design the detail of this method. See Figure 5-29.

A. Recommended Method

1. Restrict traffic flow as required to facilitate the repair.
2. Cut holes in the deck large enough to accommodate piles battered as necessary. The holes in the deck should be as close to the end diaphragm as possible to minimize length of the sub-cap.
3. Drive piles and cut off at level sufficiently below pier cap to accommodate the sub-cap support beams.
4. Weld sub-cap support beams to the piles. Piles may be bent to a slight degree to match the sub-cap.
5. Shim cap for fit to the existing pier cap.

6. Close deck holes; restore traffic.

5.9.2 Crutch Bent

The District Bridge Engineer shall design the detail of the crutch bent.

A. Recommended Method

1. Layout location on deck for crutch bent piles.
2. Cut 30 inch square hole in deck at each pile location. Cut conflicting reinforcing steel at center of hole and bend out of the way to allow pile to pass.
3. Set piles and drive to specified bearing.
4. Cut off piles 18 inches below bottom of existing cap.
5. Bend deck reinforcing steel back into position and cover holes in deck temporarily by placing a 3/8 inch steel plate over hole.
6. Set bottom cap form around pile.
7. Place reinforcing for cap.
8. Set and form tie end and side cap forms.
9. Remove temporary deck hole covers and place tremie through holes for pouring concrete.
10. Place concrete in cap form in layers. Vibrate each layer by letting vibrator penetrate into top of preceding layer.
11. Trowel finish top of cap and apply curing compound.
12. Remove forms from concrete after reaching desired strength.
13. Splice cut reinforcing bars in deck as required.
14. Form bottom of deck holes and place concrete. Broom finish and cure concrete.

5.9.3 Timber Helper Bent

Driving timber piles through deck parallel and adjacent to existing pile bent and placing timber cap on top of piles. This repair is used when existing piling have lost bearing and settlement occurs or when pilings have deteriorated to the point that their load carrying capacity is in question. See Figure 5-30.

A. Recommended Method

1. If deck is timber overlaid with asphalt or concrete, locate centerline of beams closest to each pile location for the helper bent. If deck is reinforced concrete, locate piles so

that deck beams will not interfere with driving.

2. Cut holes in only one lane of traffic at a time.
3. Cut through overlay and timber deck along centerline of beam. Remove sufficient number of timber decking to permit pile to go through hole. For reinforced concrete deck, remove sufficient amount of concrete in a square pattern to permit pile to go through hole. Cut reinforcing steel at center of hole and bend back out of the way of pile. If timber deck is not overlaid, cut timber decking at centerline of beam near centerline of bridge and remove decking across travel lane.
4. Set piling and drive to required bearing.
5. Cut off piling approximately 1/4 inch above bottom of existing cap. If existing cap has settled, allowance must be made for grade differential.
6. Place cover plates over deck holes, open lane to traffic and move to adjacent lane, repeating operation.
7. After all piles have been driven and cut off, jack up superstructure approximately 1/2 inch using existing pile bent.
8. Place timber cap over both rows of piling. For end bents, only one row of piles and cap is required.
9. Lower superstructure onto new caps and strap cap to piling. Shimming may be required to obtain bearing between superstructure and timber cap.
10. Remove deck plates and reconstruct deck. If deck is reinforced concrete, splice cut bars. Replace deck in one lane at a time.
11. Erect cross bracing on new pile bent. For intermediate bents, cross-bracing between the two new bents is also required.

5.9.4 Temporary Steel or Timber Helper Bent

Drive piles outside of existing bent, erect timber cap on piles and set steel beams under existing bent. Use this repair method when the overall deterioration of the piles and/or bearing areas is 50 percent or greater. This repair is used where existing piles are timber. This is a temporary type repair and should be used only on bridges that are scheduled for replacement within a few years. The District Bridge Engineer shall design the detail of the helper bent. Use approved jacking method for lifting superstructure. See Figure 5-31.

A. Recommended Method

1. Set piles and drive to specified bearing.
2. Cut off piles to allow for beams, neoprene pads and wedge plates.
3. Connect 12 inch X 12 inch timber cap to plates with 7/8 inch diameter X 1 foot-9 inch headless drive spikes.
4. Connect timber brace to piles.
5. Set steel beams into position (Beams may be W21 X 55 or W21 X 62).
6. Jack beams off cap to obtain temporary bearing against superstructure.
7. Set neoprene pads into position.
8. Place and drive wedge plates as necessary to obtain bearing.
9. Remove jacks and drive lag bolts.

5.9.5 Helper Bent or Crutch Bent

Helper bents are installed under sound pier caps to provide support after existing piles have deteriorated or settled out of position. The existing pile cap must be in sound structural condition. This repair requires piles to be driven through deck slab, thus the bridge must be able to support the weight of pile driving equipment. Dry land or floating pile-driving rig could also be used.

A. Recommended Method

1. Restrict traffic to one lane of the bridge or close bridge if necessary.
2. Cut openings in existing bridge deck of sufficient size to allow driving of the new piles. Use temporary deck hole covers to maintain traffic during the repair. If the bridge has a reinforced concrete deck, do not cut out the rebars, but bend bars back so that the deck rebars can be restored into place by splicing new bars.
3. Drive the new piles. DO NOT cut off the piles.
4. Place cap support snug against pier cap and mark piles for cut off.
5. Cut off new piles.
6. Wedge cap support into position atop the new piles and fix by any suitable method.
7. Remove the temporary deck hold covers and close.

5.10 DEADMAN ANCHORAGE INSTALLATION

The force of earth and stone in the bridge approach, behind the bridge abutment, tends to push the abutment forward and may tend to rotate (tip over) the abutment. These forces may exceed the resistance of the abutment if the fill behind the abutment is unstable or the abutment is not adequately anchored. Deadmen are heavy masses (weights), usually concrete blocks, attached to the abutment with long steel rods and located in stable earth well behind the abutment to provide an anchor to prevent overturning of the abutment. See Figure 5-32. Engineering calculations are required to determine the magnitude of the forces to be resisted by the deadman, and to determine the size of the deadman, the size of the restraining rod, and whether piles are required or not.

A. Recommended Method

1. Excavate the area where the deadmen are to be placed and provide a trench for the restraining rods.
2. Drive piles for the deadmen if required.
3. Place form work and concrete for the deadmen. Note that the side of the deadmen facing the abutment should be cast without forms. All forms may be eliminated if the condition of the excavation permits.
4. Drill through the wing walls and place the restraining rods. Wrap and coat with tar or provide other means to protect rods from corrosion.
5. Bolt the restraining rods to the deadmen.
6. Place the waler beams and tighten the rods.
7. Back fill.

5.11 ABUTMENT REPAIRS

5.11.1 Abutment Face Repair

The concrete in abutments may deteriorate from the effects of water, sea salt, and debris impact. This condition requires that repairs be made to prevent continued deterioration, particularly increased spalling due to moisture reaching the rebar and causing corrosion. The procedure is often used to re-face old rubble masonry or concrete made from large stone. See Figure 5-33. The following steps in the rehabilitation procedure are normally required:

A. Recommended Method

1. Establish traffic control, if necessary.
2. Remove deteriorated concrete and laitances by chipping and blast cleaning.
3. Drill and set the tie screws and log studs to support the form work.
4. Set reinforcing steel and forms.
5. Apply epoxy-bonding agent to the concrete surface just before placing the concrete.
6. Place the concrete, cure, remove the forms.
7. Install erosion control material.

5.11.2 Backwall Repairs

Abutment backwall damage caused by pressure from approach pavements can be avoided by installing relief joints, as described under Bridge Deck Maintenance & Repair. To repair a cracked backwall, the following procedure can be used. This method is used to repair the abutment backwalls for the full width of the structure between abutment parapets, and to a depth sufficiently below the bridge seat elevation to permit the installation of dowels or the proper lapping of reinforcing bars. See Figure 5-34.

A. Recommended Method

1. Temporarily tack weld the abutment side of the steel armored joints, sliding plate expansion joint, or toothed expansion joint to the deck side of the joint assembly.
2. Cut and excavate the approach slab or pavement to allow access to the backwall.
3. Remove deteriorated concrete or masonry and/or reinforcing bars from the backwall.
4. Place replacement reinforcing bars by tying them into existing bars in the abutment or by grouting dowel bars into the abutment.
5. Place forms for concrete.
6. Place and cure concrete. Ensure concrete is placed beneath existing joints.
7. Remove forms and temporary tack welds on joints or dams.
8. Backfill and compact sub-grade under the approach slab or pavement.
9. Patch the approach slab or pavement.

5.12 WINGWALL REPAIRS

5.12.1 Concrete Wingwall Repairs

Repair the concrete wingwalls by removing deteriorated portions of the wall and replaced with new concrete. This method is used to repair the deteriorated concrete and to restore the structural integrity of the wingwalls. See Figure 5-35.

A. Recommended Method

1. Excavate as required to set dowels and forms.
2. Remove all fractured or deteriorated concrete to sound concrete by chipping, and blast clean to remove laitances.
3. Drill and set form anchor bolts and dowels. Dowels are to be placed a minimum of 9 inches into sound concrete and set with non-shrink grout or approved adhesive, 18 inches on center, front and back.
4. Cross-lace the #4 reinforcing bars and set forms.
5. Just prior to placing concrete, apply epoxy bonding agent to all existing concrete that is to come into contact with new concrete.
6. Cure concrete until concrete has developed sufficient strength to resist the imposed lateral pressures before backfilling with granular material.
7. Backfill and provide erosion protection as necessary.

5.12.2 Wingwall Extension Using Gabions

Extend the abutment wingwalls by gabion structure. This method is used to extend the abutment wingwall in order to retain the material behind the wingwalls. See Figure 5-36.

A. Recommended Method

1. Excavate and remove all unsuitable material below the wingwall extension.
2. As required, replace unsuitable material with acceptable granular material and thoroughly compact the entire foundation to a firm, even surface.
3. Place specified geotextile fabric or place concrete pad.
4. Assemble, bind, join, and place gabions.

5. Fill gabions by hand or small power equipment, with specified aggregate.
6. As specified, secure lid to sides, ends, and diaphragms using connecting wire.

5.12.3 Wingwall Stabilization Using Gabions

Stabilize existing wingwalls by removing unsuitable material below the wingwall and replace with acceptable granular material and place gabions in front of the wingwalls. This method is used to stabilize the wingwall which has a weak foundation or scouring problems. See Figure 5-37.

A. Recommended Method

1. Excavate and remove all unsuitable material below the face of wingwall to be retained or stabilized.
2. As required, replace unsuitable material with acceptable granular material and thoroughly compact the entire foundation to a firm, even surface.
3. Place specified geotextile fabric or place concrete pad.
4. Assemble, bind, join, and place gabions.
5. Fill gabions by hand or small power equipment, with specified aggregate.
6. As specified, secure lid to sides, ends, and diaphragms using connecting wire.
7. Place specified large rock buttress at a 1:1 slope.

5.13 REINFORCED EARTH WALL REPAIRS

5.13.1 Panel Replacement

Replace impact damaged concrete facing panels by stabilizing the reinforced volume, removal of the damaged panel, and installation of a new special reinforcement panel.

A. Recommended Method

1. Drill grout holes through the facing panels 1 inch in diameter, spaced about 18 inches apart. See Figure 5-38.
2. Starting at the lowest hole, inject a cement/water mixture using gravity pressure only. Start with the bottom holes and work up to the highest holes.

3. Drill an access hole in the panel directly above the damaged panel. This access hole will allow a visual inspection of the grout, and later, a means of filling behind the replacement panel with sand.
4. Using an oxy-acetlyene torch, burn away the construction pin at each corner of the panel. This will free the corners and allow for horizontal removal of the concrete. Wedges are placed in all adjacent panels.
5. Using a circular saw with a diamond concrete blade, cut the top of the panel above the reinforcing strips. See Figure 5-39, Section "A", Cut #1. Remove the concrete and inspect the fill to verify grout consolidation.
6. Make two vertical cuts (Cuts #2 and #3), inside the reinforcing strips for the full height of the panel. See Figure 5-39. For safety purposes, make sure that the center portion of the panel is supported, connected to the crane or otherwise**,** prior to making the second cut. Remove the center piece of concrete (Section "B") and again verify grout consolidation.
7. Working through the open center of the panel, clear backfill away from the tie-strip connection to the reinforcing strips. Remove the connection bolt.
8. The two remaining outside pieces of the panel (Sections "C" & "D"), can now be removed.
9. Attach two special tie-strips to each reinforcing strip using a single bolt connection.
10. Using the swift-lifting eyes on the back of the new replacement panel, lift the unit and swing it into position. Install a new cork strip at the base of the opening and seat the panel base first.
11. Prop up the panel with bracing. Then disconnect the lifting eyes from the inserts at the back of the panel and connect the eyes to the inserts on the top-front of the panel**.**
12. Remove the bracing and lift by the front inserts until the panel pulls into position. All exposed tie-strips should project through the special access holes of the panel.
13. Brace the panel in place.
14. Place tension on the reinforcing strips by jacking.
15. Tack weld all tie-strips into place by pushing special butt-plates against the exposed reinforcing steel inside the access holes. See Figure 5-40.
16. Using the torch, cut off all excess tie-strip length.

17. Complete all welds to 100 percent.
18. Insert foam into the vertical joints between panels.
19. Using the access hole (drilled in the panel directly above the new panel), hydraulically fill the void behind the new panel with sand until all visible voids are filled.
20. Patch all access holes and lifting insert holes with epoxy concrete.
21. Finish the panel by sacking or coating the face to blend with adjacent panels.

5.14 PIER REPAIRS

5.14.1 Repair of Deteriorated Concrete

Repair to concrete piers is accomplished by removing deteriorated or damaged concrete and placing new concrete. This method is used to restore the integrity of concrete piers that have spalls, cracks, voids, etc. See Figure 5-41. The first step in the repair of any type of deterioration in concrete is complete removal of all unsound concrete. No satisfactory repairs can be made until there is clean and sound concrete to which the new concrete can be bonded. The edge of a cut out area should be undercut for deep patches to help retain the new material.

Effective bonding of the new to the old concrete is usually accomplished with a bonding material and is particularly important when deep cracks require a large volume of concrete to be replaced. A grout can also be used when the form for the concrete is so inaccessible that an epoxy material cannot be applied effectively. The exposed area can be sloshed liberally with grout just prior to placing the concrete. Shotcrete may also be used in filling the crack after it is properly prepared.

A. Recommended Method

1. Saw-cut the boundaries of the deteriorated concrete to be removed to a depth of 3/4 inch.
2. Remove deteriorated concrete by chipping with light power tools.
3. Blast clean exposed reinforcing bars of all rust and foreign materials. Replace deteriorated bar sections as required.
4. Place reinforcing mesh as necessary.
5. Blast clean the existing concrete to be patched to remove loose concrete chips and laitances.

6. Place forms, coat existing concrete surfaces with epoxy bonding agent, and place concrete.
7. Remove forms and finish surfaces after the concrete has cured.

5.14.2 Repair of Cracked Piers

A. Vee Crack Repair

A footing may crack transversely due to uneven settlement of the pier or abutment. This will often be accompanied by a crack continuing up through the pier (or abutment). It is advisable to seal the crack to prevent further intrusion of silt, debris, and water that will attack the reinforcing steel. If the crack is moving, it should be filled with a flexible material; otherwise, it will crack again. If the crack is not moving, it can be bonded back together again.

Cracks in substructures are generally vertical. The most effective method of repairing these cracks is epoxy injection. In order to get maximum penetration of the epoxy filler, the first injection is made at the bottom of the crack. Starting at the bottom and moving up in gradual increments toward the top increases the pressure needed to apply the epoxy and should result in greater crack-filling penetration.

Another repair method that prevents moisture from entering the crack is to Vee the opening and fill with grout. The procedure is as follows:

1. Cut a Vee-shaped groove at the surface along the crack approximately 2 to 3 inches in width using a small pneumatic chisel.
2. Thoroughly flush and blow out the crack using water and high pressure air.
3. Secure a retaining form on the face of the concrete surface over the vertical portion of the crack.
4. Wet the surfaces of the crack thoroughly by pouring liberal quantities of water into it. Fill the crack with a cement (or epoxy) and fine sand grout in a 1:2 mix that runs freely.

5. Clean out the Vee'd portion of the surface after the grout has partially set and apply bonding compound or a neat cement base to the surface of the Vee; then fill the Vee with a stiff grout mixture.

B. Post Tensioning Cracked Hammerhead Piers

Repairs of cracked hammerhead piers can be accomplished by externally post tensioning both sides of the hammerhead cap. This repair method can be used to close major cracks and to restore the capacity of the pier cap. See Figures 5-42 and 5-43. The following procedure is suggested:

1. Erect all intermediate tendon supports and anchorage assembly at one end of pier cap. Locate existing stirrups and horizontal steel in pier cap prior to installing expansion bolts for the supports.
2. Insert corrugated pipes with pre-grouted thread-bars into the smooth PVC pipes.
3. Erect the smooth PVC pipes with the thread-bars inside to the intermediate supports or the pier cap.
4. Erect anchorage assembly at other end of pier cap.
5. Add anchor plates with steel tubes to both assemblies, pack tubes with plastic corrosion inhibitor and add anchor units on both ends.
6. Initially post tension all thread-bars to 10 kips in order to seat the post tensioning system on the pier cap.
7. Epoxy inject all cracks in the pier cap.
8. After the injected epoxy has hardened, post tension the system to the required load per bar.
9. Install sealing caps with plastic corrosion inhibitor and plastic nuts.

5.15 UNDERWATER REPAIRS

5.15.1 Engineering For Underwater Repairs

It is important that solutions to underwater problems are based on sound engineering. There is a tendency to make the solution fit one of a few common underwater repair techniques. A major concern is that the repair may only hide a structural problem while it continues to worsen, as is the case when pile jackets are installed in a marine environment without consideration of cathodic protection systems. For example, when contaminated concrete and corroded reinforcing steel are left in place to interface with new concrete, the corrosion process actually accelerates. Consequently, covering a reinforced concrete member with a stay-in-place form or jacket will not stop or prevent further corrosion of the reinforcement. The member may look satisfactory while it is deteriorating to an unsafe condition.

Since most bridge engineers are not divers, it is important that they understand the problems and limitations in performing an underwater repair. All repair schemes used above water are not cost effective when performed by divers in underwater conditions. It may be less expensive to accept that the deterioration will continue and modify the load path by designing the repair to support the total load or by designing a supplemental supporting system than to remove and replace the damage.

5.15.2 Pressure Injection of Cracks Underwater

When cracks expose the reinforcing steel to moisture, the stage is set for the corrosion process to begin. In saltwater environments, corrosion can occur very fast. With proper selection of water-compatible adhesive, normally an epoxy resin, dormant (non-moving) cracks saturated with water can be repaired. The procedure can also repair other small voids such as delaminations or honey-combed areas near the surface of the concrete. Pressure injection can be used, within limits, against a hydraulic head provided the injection pressure is adjusted upward to counteract the pressure of the hydraulic head. The material must displace the water as it is injected into the crack to ensure that the crack is properly sealed resulting in a watertight monolithic structural bond.

Epoxies must have certain characteristics to cure and bond the cracked concrete together. Many adverse elements are present inside the concrete crack, such as water, contaminants carried by water, dissolved mineral salts, and debris from the rusting reinforcing steel. The typical low surface temperature of concrete underwater eliminates many products due to their inability to properly cure. The epoxy injection resins for cracks are formulated in low viscosity, and they do not shrink appreciably. The surface wet-ability of epoxy resin is of major importance, because the resin should displace all water in the crack and adhere to a wet surface and then cure in that environment.

The procedure involves cleaning of the crack by a high-pressure water system and shaping the surface of the concrete directly above the crack so that it can be sealed with a grout. Injection ports are installed in holes drilled to intersect the crack by a hydraulic or pneumatic drill. Subsequently, the surface of the crack is sealed with a grout material suitable for underwater use such as a cementitious or epoxy mortar with anti-washout admixtures and accelerators. The purpose of the grout is to retain the adhesive as it is pumped into the crack. The adhesive is pressure-injected into the crack through the ports that are embedded in the grout at regular intervals. The injection sequence begins at the bottom and advances upward. The injection moves up when the adhesive reaches and begins to flow from the port. Epoxy resin is mixed either before or after pumping. Cracks varying in width from 0.002 to 0.25 inches may be injected successfully.

Epoxy pressure injection has gained widespread acceptance as a cost effective method to bond together and seal cracked structural concrete members.

A. Precautions

1. Contaminants growing inside the crack, especially those found underwater, can reduce the successful welding of cracks.
2. Corrosion debris can also reduce the effectiveness of pressure injection.
3. Time and patience is required for the successful injection repair.
4. Injection is labor-intensive. As the temperature drops below 50 degrees Fahrenheit, it becomes more difficult to pump the epoxies into fine cracks.
5. Experience on the part of the diver in injection and the formulation of the epoxy for injection is very important.

5.15.3 Concrete Repair Underwater

A. Concrete Removal

Unless cathodic protection is used, the salt-contaminated concrete and rust must be removed from contact with existing reinforcing steel to ensure that the corrosion damage will not continue. Concrete removal can be accomplished with high-pressure water jets or with chipping hammers. Construction joints between old and new concrete should be saw-cut prior to removal to prevent feather-edges. Hydraulic or pneumatic-powered concrete saws and chipping hammers may be adapted for underwater use. Mechanical grinders are also available for cleaning concrete surfaces. Surface preparation is required after concrete removal and prior to repair. All loose and fractured concrete, marine organisms, and silt are removed by high-pressure water jets, abrasive blasting, or mechanical scrubbers. In order to reduce the accumulation of new surface deposits where the water is heavily laden with contaminants, repairs should be made the day of final surface preparation.

B. Forms

There are forming materials and forming techniques developed specifically for underwater applications. Forms are used to encase damaged concrete or masonry substructure units. Some pile jacketing forms are proprietary and marketed as a repair package. The shape, size, and location of the damaged element will often dictate the forming system used for the repairs. For underwater application, the cost of the forms is less a controlling factor than ease of erection and suitability. Commonly available polyethylene drainage pipe is also used as a form. In some repairs, it may be economical and quicker to encase all piling with a jacketing wall (one placement) rather than jacketing individual piles.

Fabric forms are relatively inexpensive and can be easily handled by a diver. While the appearance of the final repair is often irregular in thickness, shape and texture, this problem is not a problem when used underwater. Fabric forms are available with zippers for ease of installation, with spouts for pumping the repair material into the form and with pressure seals to hold the material inside the form.

C. The Mix

Anti-washout admixtures are used to minimize washout of fines and cement from the concrete that is in contact with flowing water, prevent segregation of the concrete, reduce bleeding, decrease migration of moisture within the concrete mix, and inhibit water entrainment as the concrete is placed. These admixtures tend to make the concrete sticky. A water reducer or high range water reducer may be necessary with anti-washout admixtures to maintain slump. Slumps up to 8 inches are possible. It is reported that concrete mixes containing anti-washout admixtures with either silica fume or fly ash can secure higher quality repairs at equal or lower cost than similar concretes made with high silica fume or high cement contents and no anti-washout admixtures.

D. Underwater Placement

While a limited amount of water is needed for hydration of the cement and workability of the concrete, additional water will damage the mix. As the ratio of water to cement is increased, permeability increases and strength decreases. If conventional concrete is dumped into water with no confinement as it falls through the water, it will lose fine particles, become segregated, or be completely disbursed, depending on the distance and current. Saltwater mixed with the concrete will cause corrosion of the reinforcing steel. Special techniques are necessary to protect concrete as it is placed underwater.

E. Bagged Concrete

Concrete placed in bags can be used to repair deteriorated or damaged portions of concrete or masonry substructure elements underwater. Conventional bagged concrete repairs are made with small fabric bags prefilled with dry concrete mix (often only sand and cement is used) and anchored together to form the exterior of the repair. The bags are small enough to be placed in position by hand. The interior portion of the repair is then filled with a tremie concrete or dewatered and filled with concrete. This method of repair is quick and can be performed by small crews with minimal skill and equipment. It is often used when the water is shallow enough not to require special underwater diving equipment.

Bagged concrete application was expanded when it became possible to take advantage of the durability and high strength of synthetic fibers to produce forms for casting concrete underwater. These bags possess sufficient durability for use in marine environments exposed to cyclic changes and provide sufficient abrasion resistance. The properties of fabric-formed concrete are essentially the same as those expected of concrete cast in conventional rigid forms with one exception: the water-cement ratio of the concrete can be quite low at the surface since the permeable fabric allows bleed water to expel through these bags.

F. Prepacked Aggregate Concrete

In this method, after the area to be repaired is properly prepared and forms are in place, graded course aggregate is placed in the form. A cement-sand grout is then injected into the area containing the aggregate, displacing the water and filling the voids between the aggregate. This technique is particularly effective for underwater repairs where it would be difficult to place premixed concrete because of forming restrictions. Generally, an expansive grout with a fairly high water-cement ratio is used to provide fluidity. When anti-washout admixtures are added to the grout, forms do not have to be watertight.

G. Tremie Concrete

Tremie concrete is placed underwater through a gravity-filled pipe, which is called a tremie. The underwater portion of the pipe is kept full of plastic concrete at all times during the placement. Concrete placement starts at the lowest point and displaces water as it fills the area. A mound of concrete is built up at the beginning of the placement. The bottom of the tremie must stay embedded in this mound throughout the placement to seal the tremie. The concrete is forced into the occupied area by gravity from the weight of the material in the tremie. The thickness of placement is limited to the depth of the mound of concrete.

Tremie concrete is best suited for larger volume repairs where there will not be a requirement to relocate the tremie frequently or for deep placements where it would not be practical to pump the concrete. Tremie concreting is simple with little equipment to malfunction. It is the most common method of placing concrete underwater.

H. Pumped Concrete

Pumped concrete is placed underwater using the same equipment as above water. It is placed in a similar manner as tremie concrete except that the problem of getting the concrete into the tremie is eliminated. A direct transfer of concrete is provided, and the pump provides the force in moving the concrete. Unlike tremie, relocation is not a problem. As with tremie, the placement must start at the bottom and the hose or pipe must stay submerged in the fresh concrete during placement but there is less need to lift the pipe. A handle on the end of the pipe will help the diver position the pipe.

I. Free Dump Concrete

Within recent years, anti-washout concrete admixtures have been developed to minimize the loss of fines and reduce segregation when it is placed under water. This admixture makes the concrete mix more cohesive, yet sufficiently flowable for placement. It loses some of the self-leveling properties and tends to stick to equipment. Evidence of this method's success to date is somewhat limited. Therefore, it should be used with caution, when high quality concrete is not a primary consideration, and only when there is minimal water current and drop distance is no more than about 3 feet.

J. Hand-Placed Concrete

Hand-placed concrete is mortar or concrete that is placed by hand by the diver and packed or rammed for consolidation. This method is best suited for isolated repair sites. Use of accelerators, anti-washout admixtures, and a low water-cement ratio is recommended. The method is best suited for deep and narrow cavities. The concrete can be delivered to the diver by bucket on a rope conveyor assembly or can be dropped to the diver in baseball-sized quantities through a pipe with holes cut in the sides to allow displaced water to escape, easing the descent of the concrete. Small quantities needed for patching can also be delivered to the diver in plastic bags.

Figure 5-1
Cathodic Protection - Small Zinc Anodes

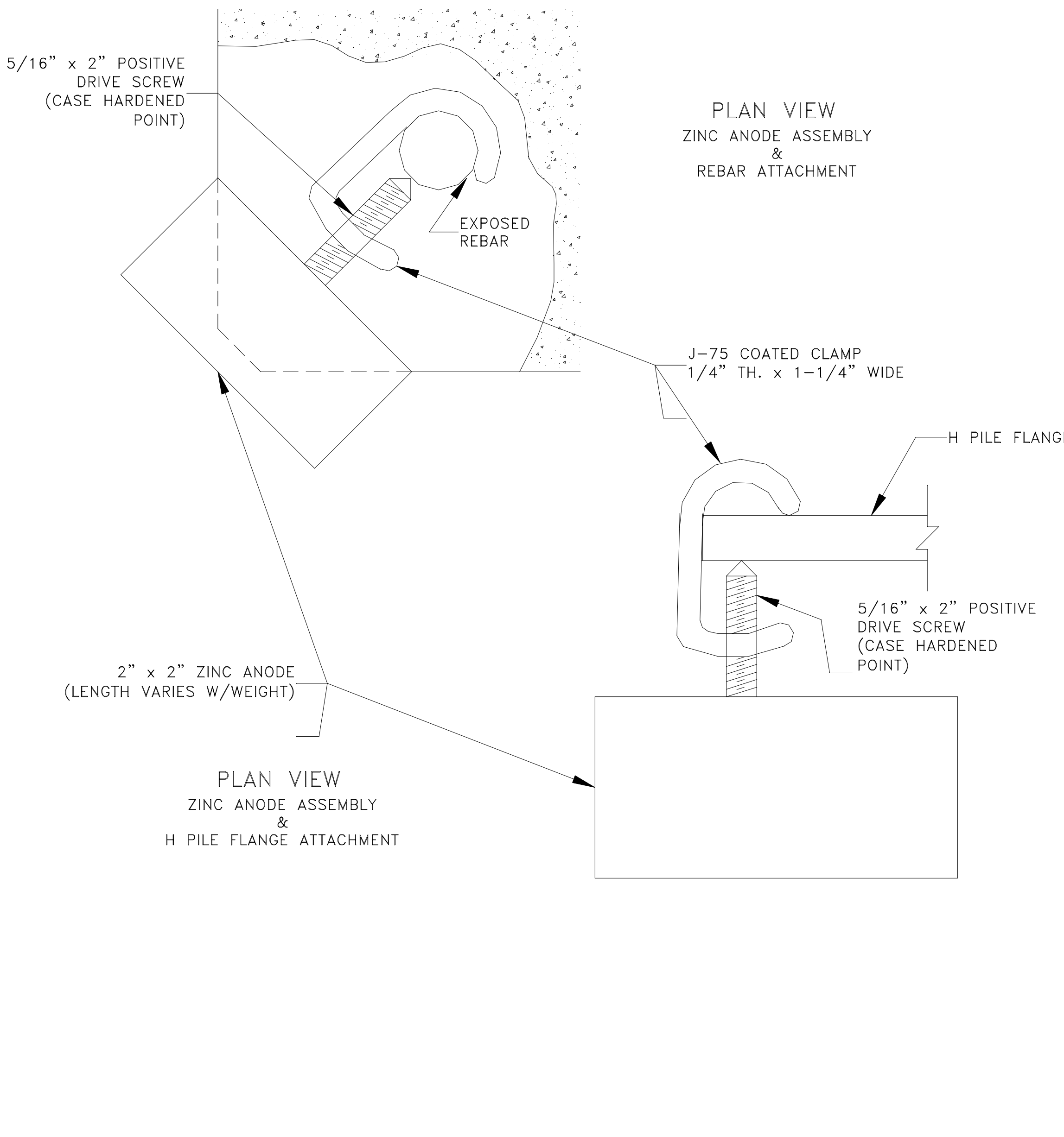


Figure 5-2
Cathodic Protection - Small Zinc Anodes

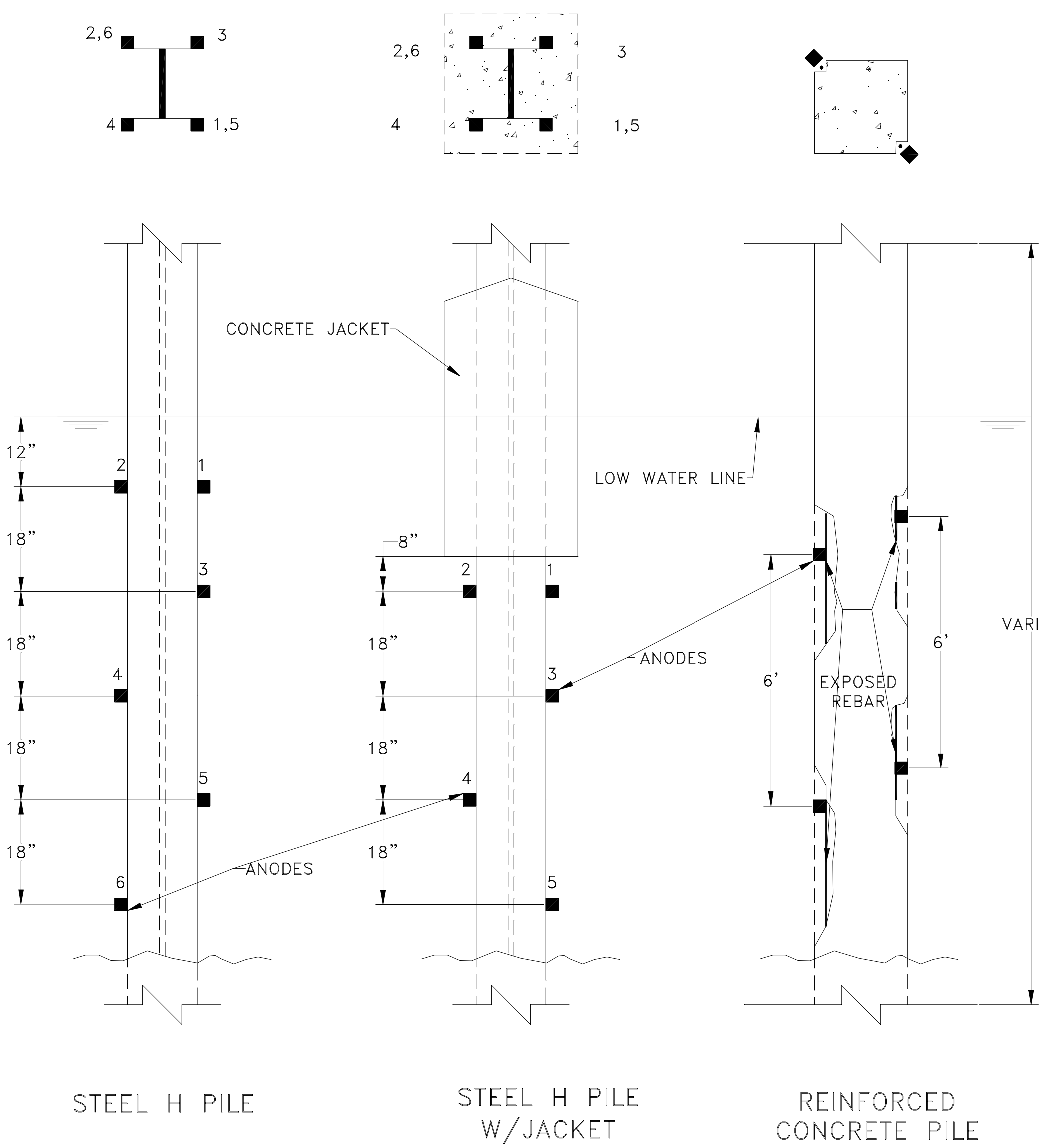


Figure 5-3
Cathodic Protection - Large Zinc or Aluminum Anodes

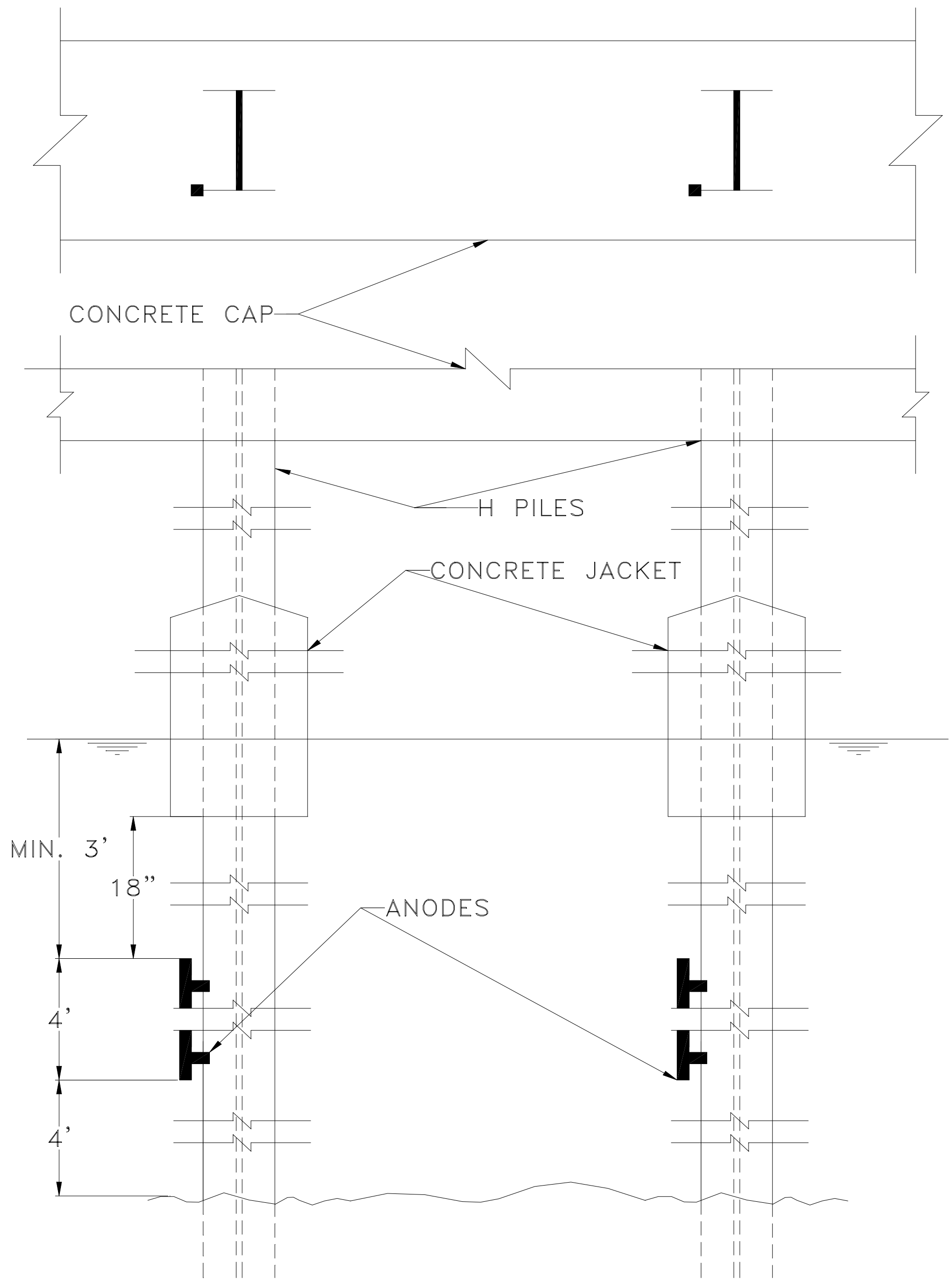


Figure 5-4
Cathodic Protection - Large Zinc or Aluminum Anodes

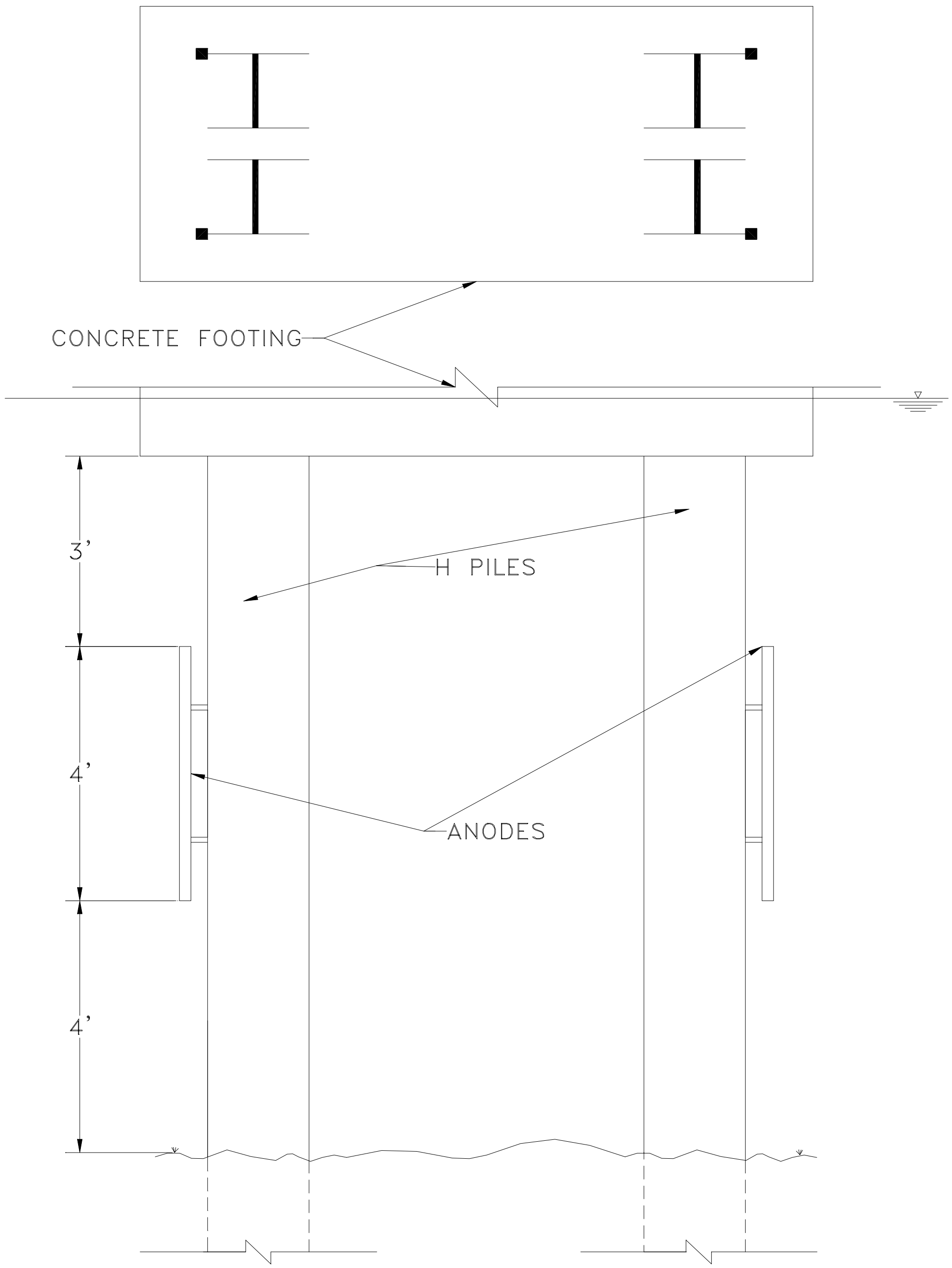
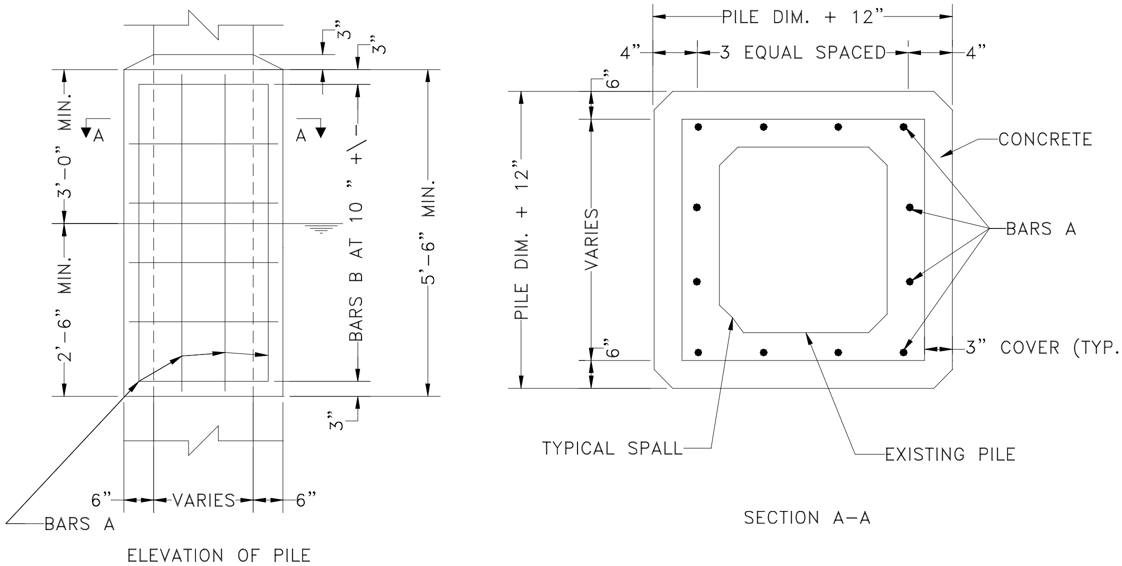
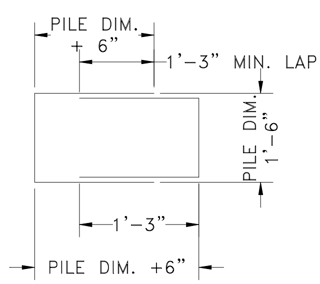


Figure 5-5
Reinforced Concrete Pile Jacket



BILL OF REINFORCING STEEL			
MARK	SIZE	NO. REQ'D.	LENGTH
A	5	12	MIN. 5' - 0"
B	4	MIN. 7	VARIES

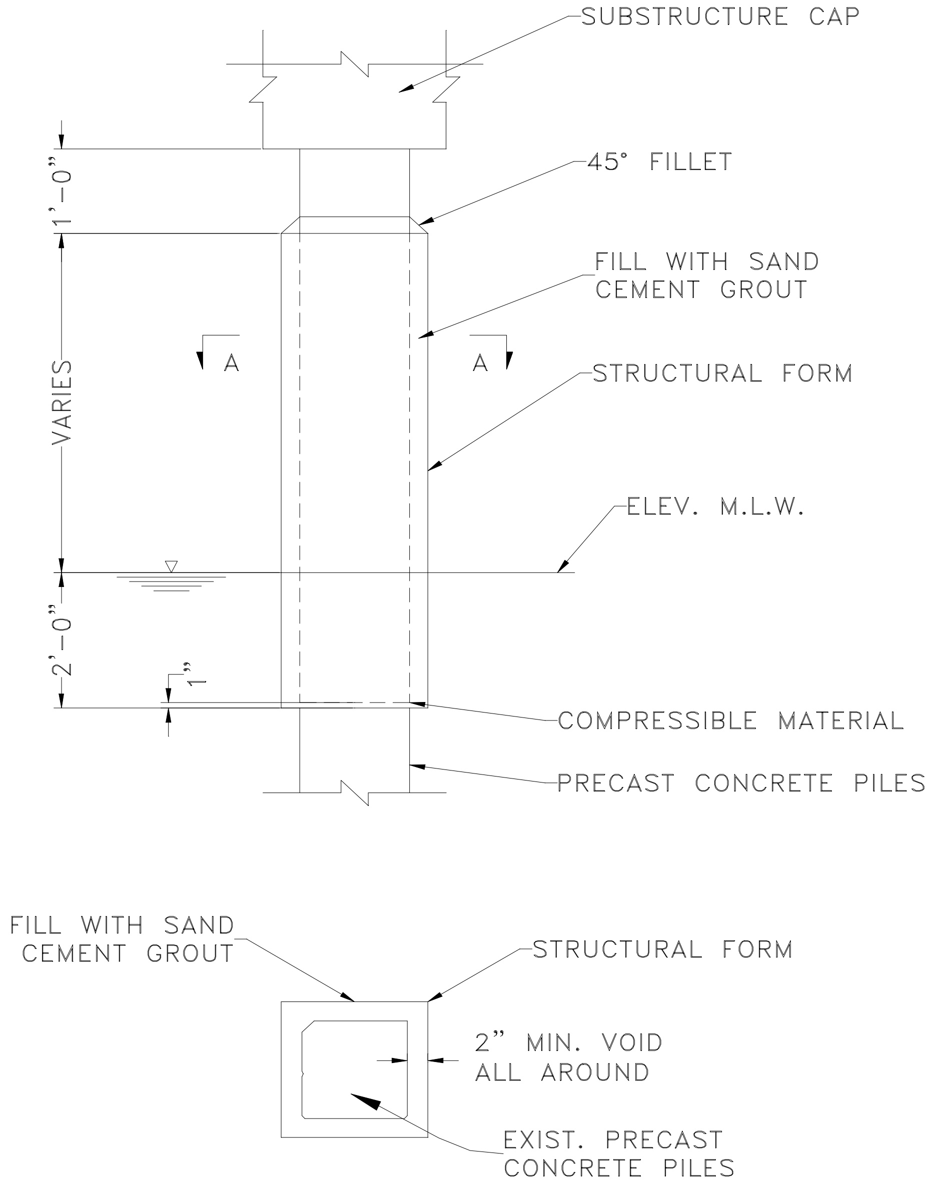
BENDING DIAGRAMS



BAR B

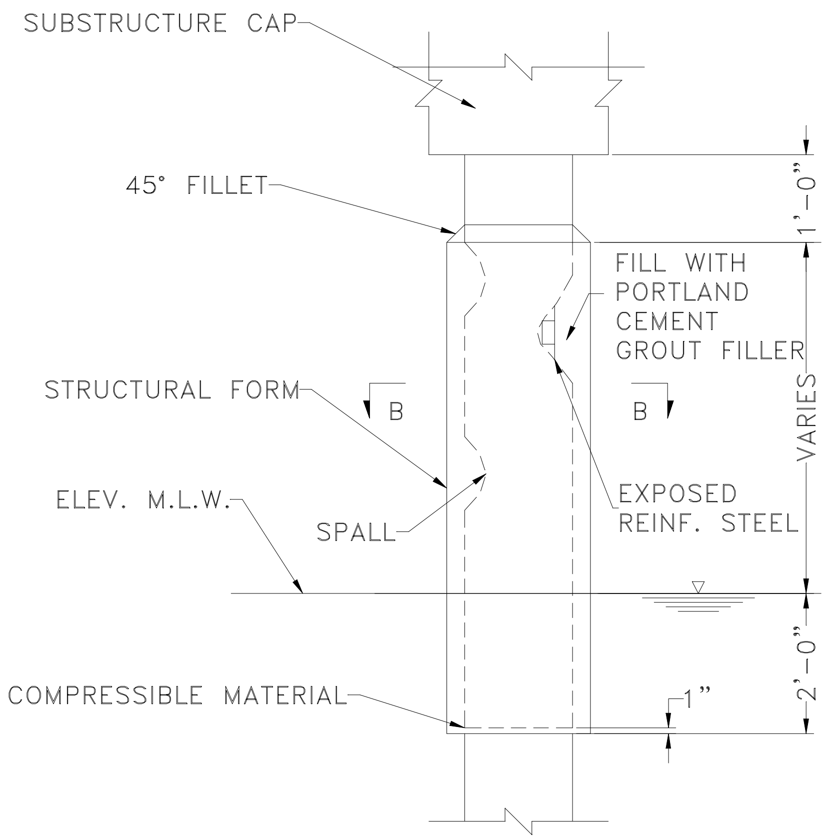
NOTE: ALL BAR DIMENSIONS ARE OUT-TO-OUT.

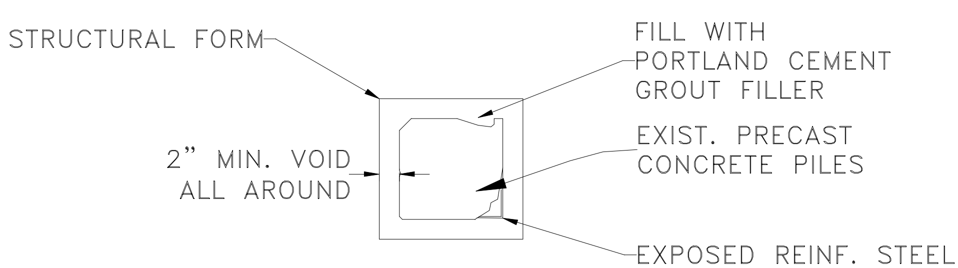
Figure 5-6
Fiberglass Pile Jacket
Type 1 - Epoxy Filler With Jacket In Splash Zone



SECTION A–A

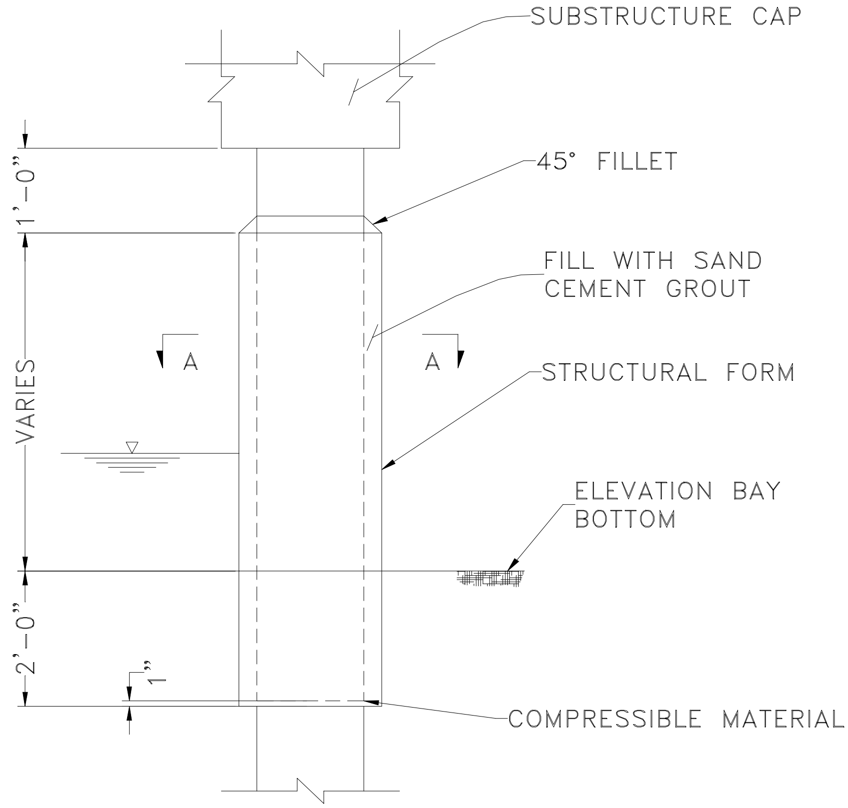
Figure 5-7
Fiberglass Pile Jacket
Type 2 - Cement Filler With Jacket In Splash Zone

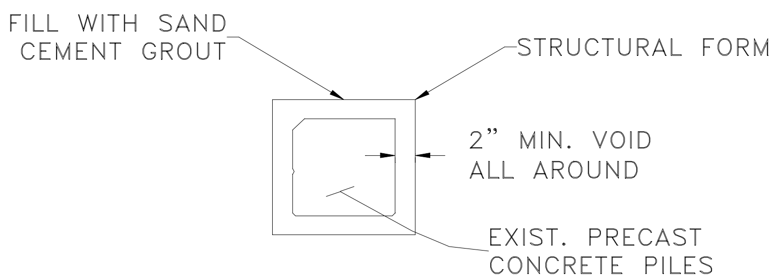




SECTION B–B

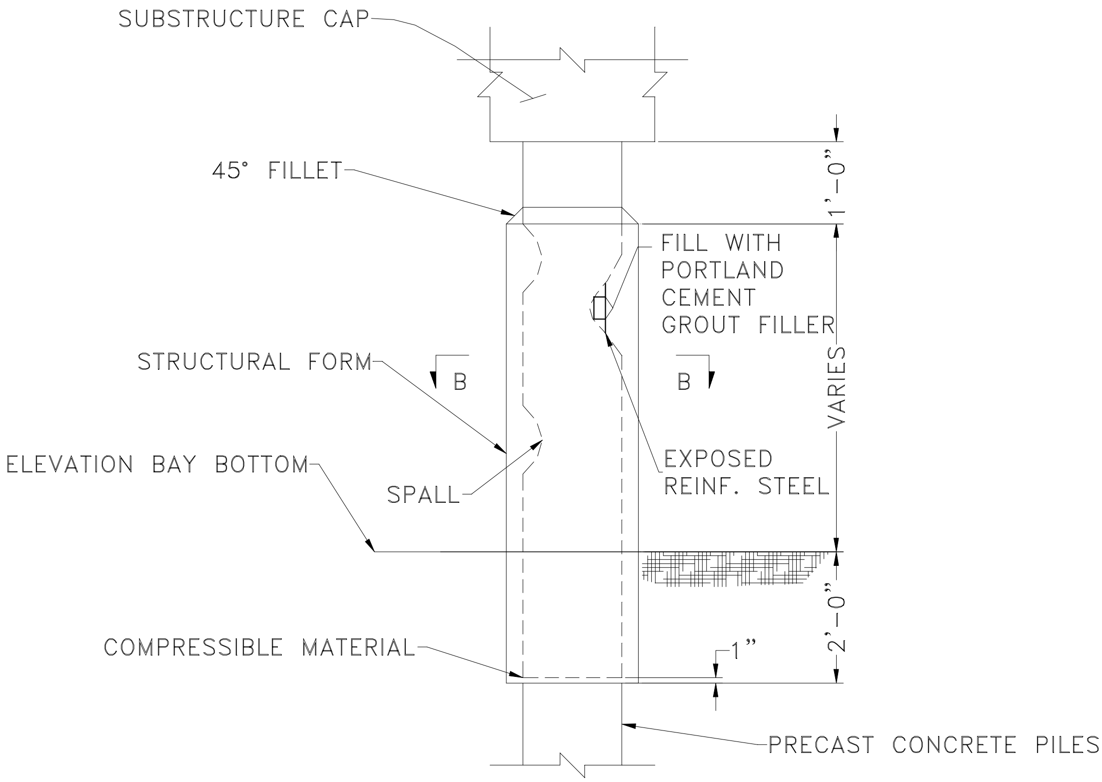
Figure 5-8
Fiberglass Pile Jacket
Type 3 - Epoxy Filler With Jacket Into Channel Bottom

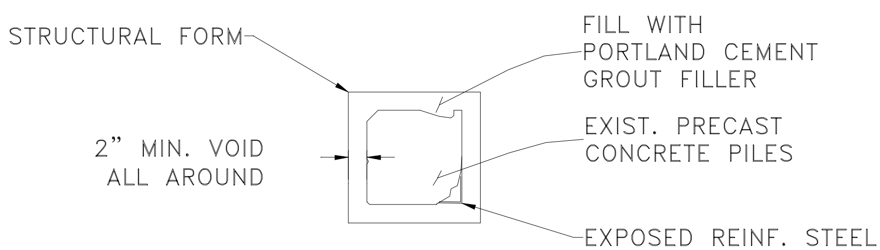




SECTION A–A

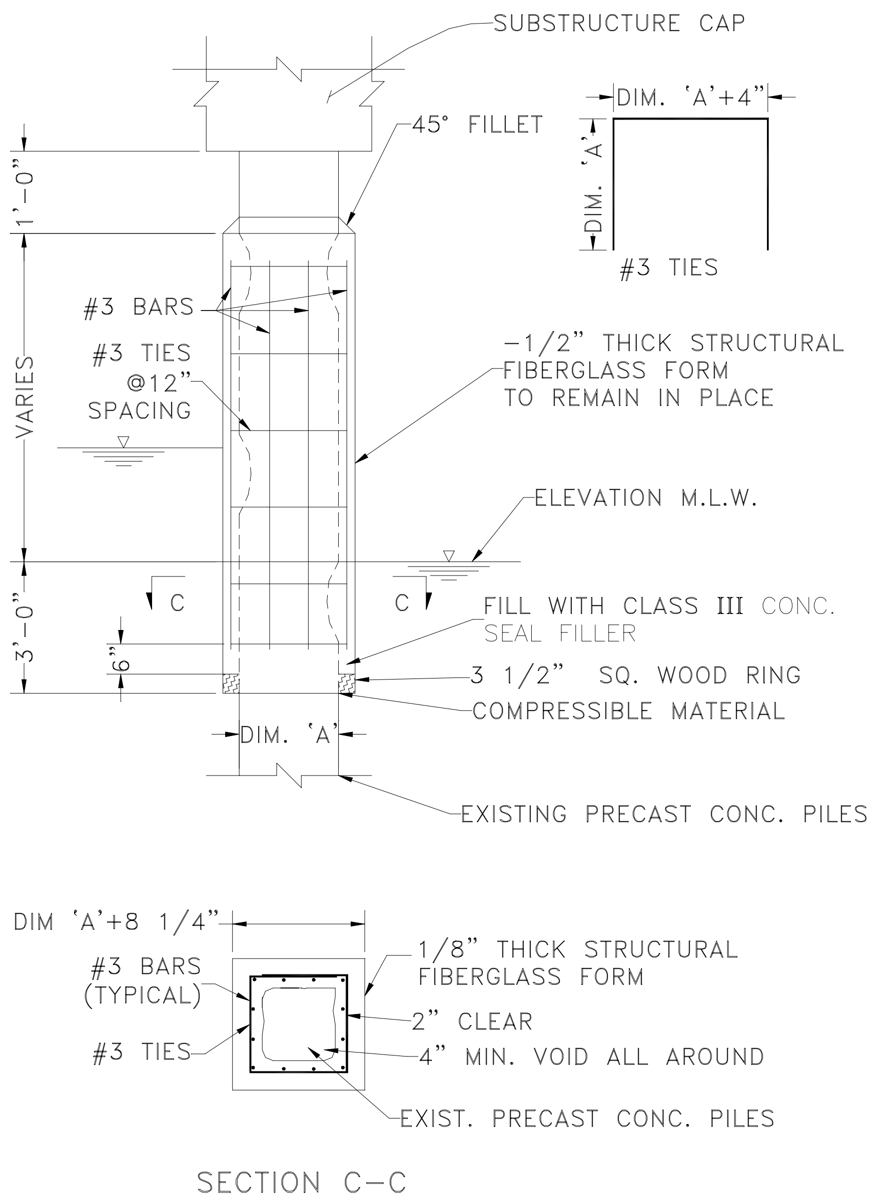
Figure 5-9
Fiberglass Pile Jacket
Type 4 - Cement Filler With Jacket Into Channel Bottom





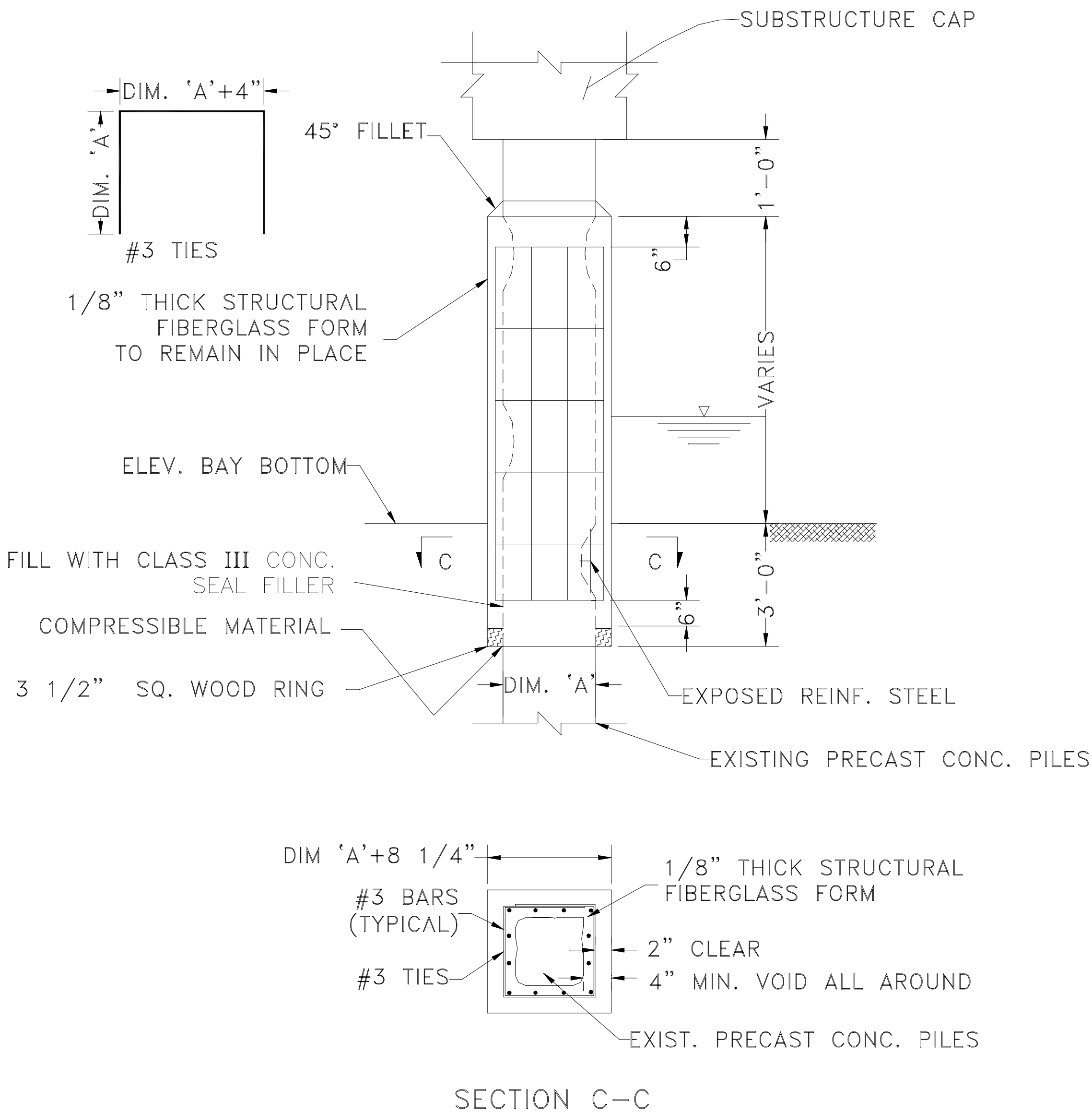
SECTION B—B

Figure 5-10
Fiberglass Pile Jacket
Type 5 - RC Filler With Jacket In Splash Zone



NOTE: AN EXTERNAL BAND SHALL BE DRAWN AGAINST THE WOOD RING SEAL DURING PLACEMENT OF SEAL CONCRETE.

Figure 5-11
Fiberglass Pile Jacket
Type 6 - RC Filler With Jacket Into Channel Bottom



NOTE: AN EXTERNAL BAND SHALL BE DRAWN AGAINST THE WOOD RING SEAL DURING PLACEMENT OF SEAL CONCRETE

Figure 5-12
Fiberglass Pile Jacket on H-Pile
Type 7 - Cement Filler With Jacket In Splash Zone

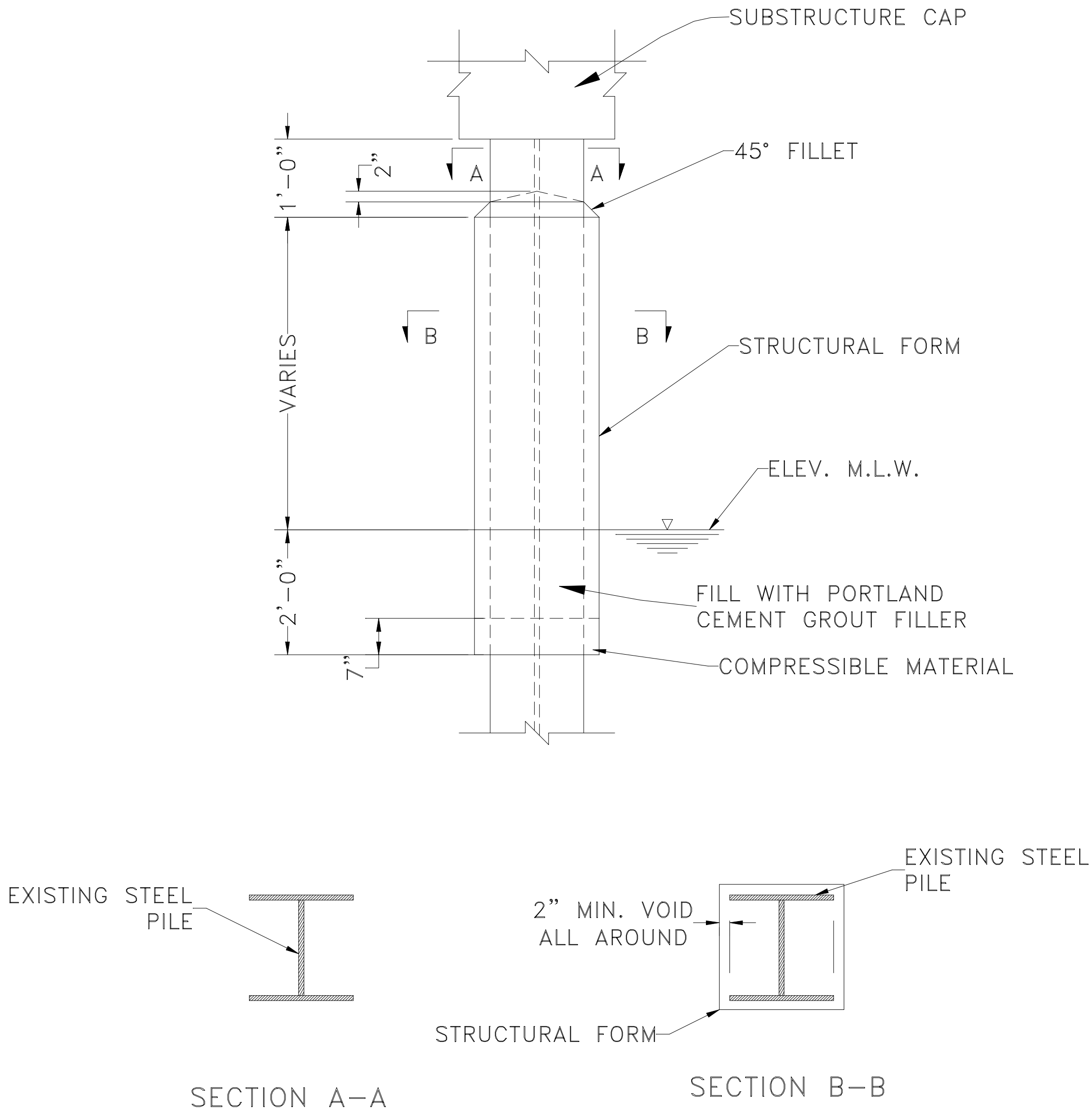
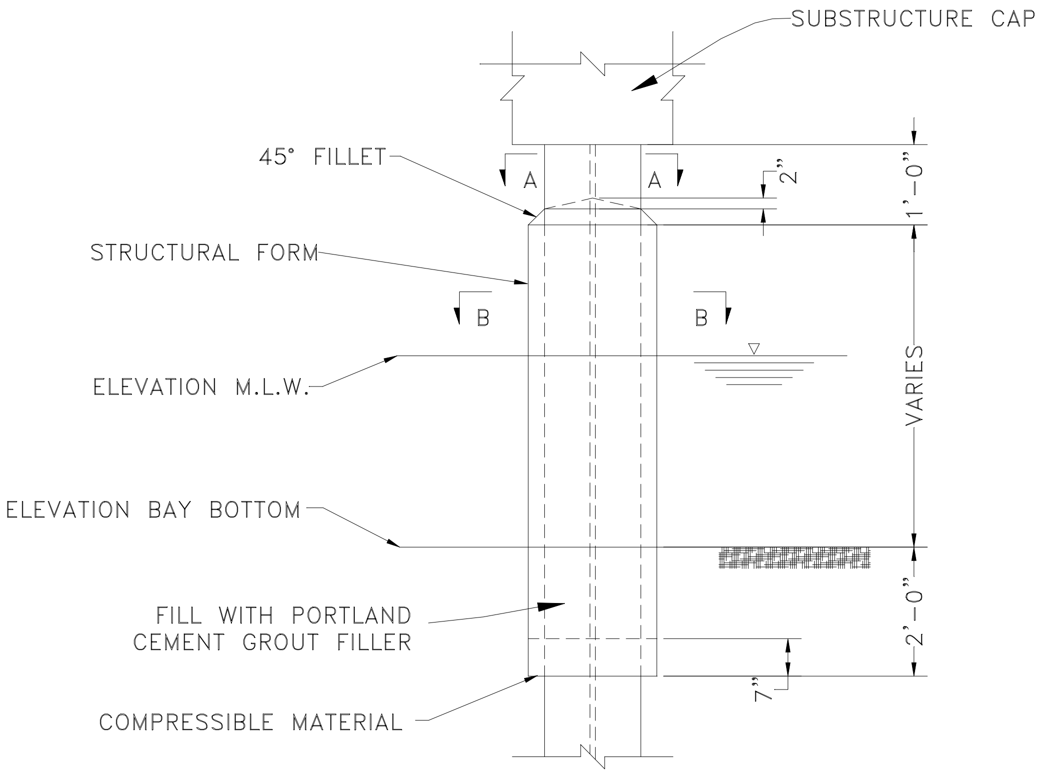
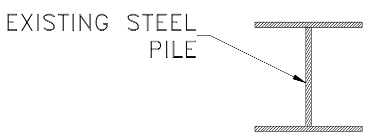
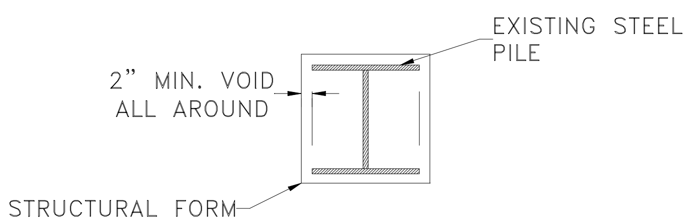


Figure 5-13
Fiberglass Pile Jacket On H-Pile
Type 8 - Cement Filler With Jacket Into Channel Bottom



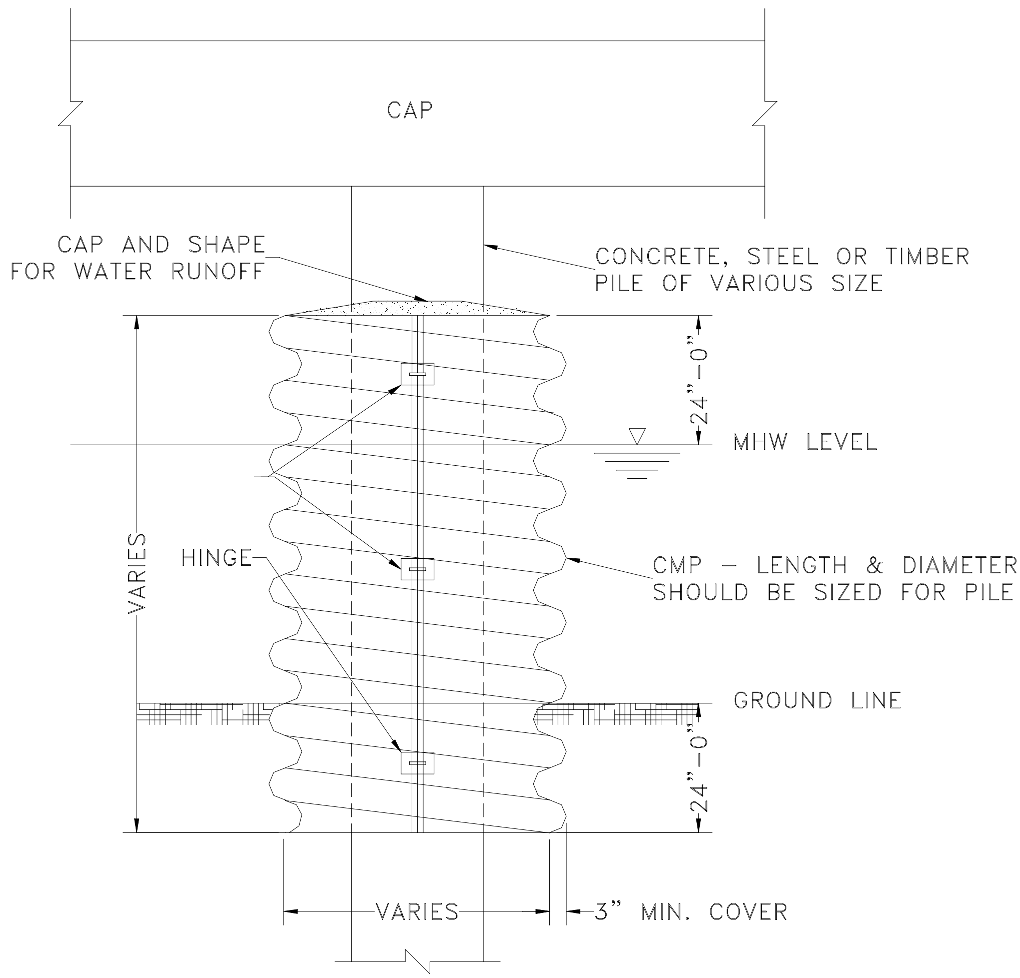


SECTION A-A



SECTION B-B

Figure 5-14
Corrugated Metal Pile Jacket



NOTE: HINGES & LATCHES TO BE WELDED TO CORRUGATED METAL PIPE. AFTER WELDING/BURNING HAS BEEN COMPLETED, TREAT AREAS INVOLVED WITH CORROSION PROTECTANT.

Figure 5-15
Fabric Pile Jacket

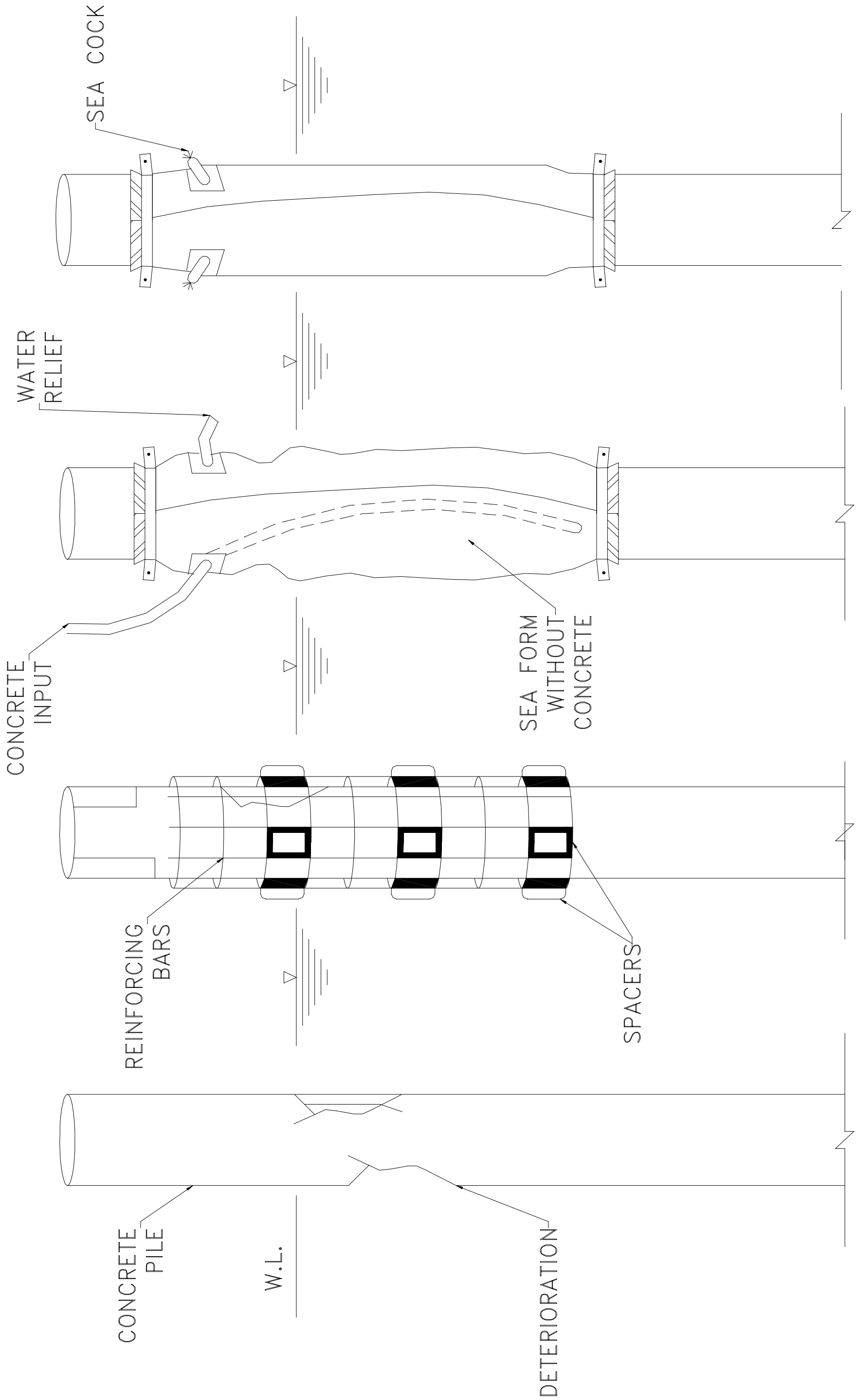


Figure 5-16
Sacrificial Cathodic Protection System Pile Jacket For Rebar Reinforced Concrete Piles

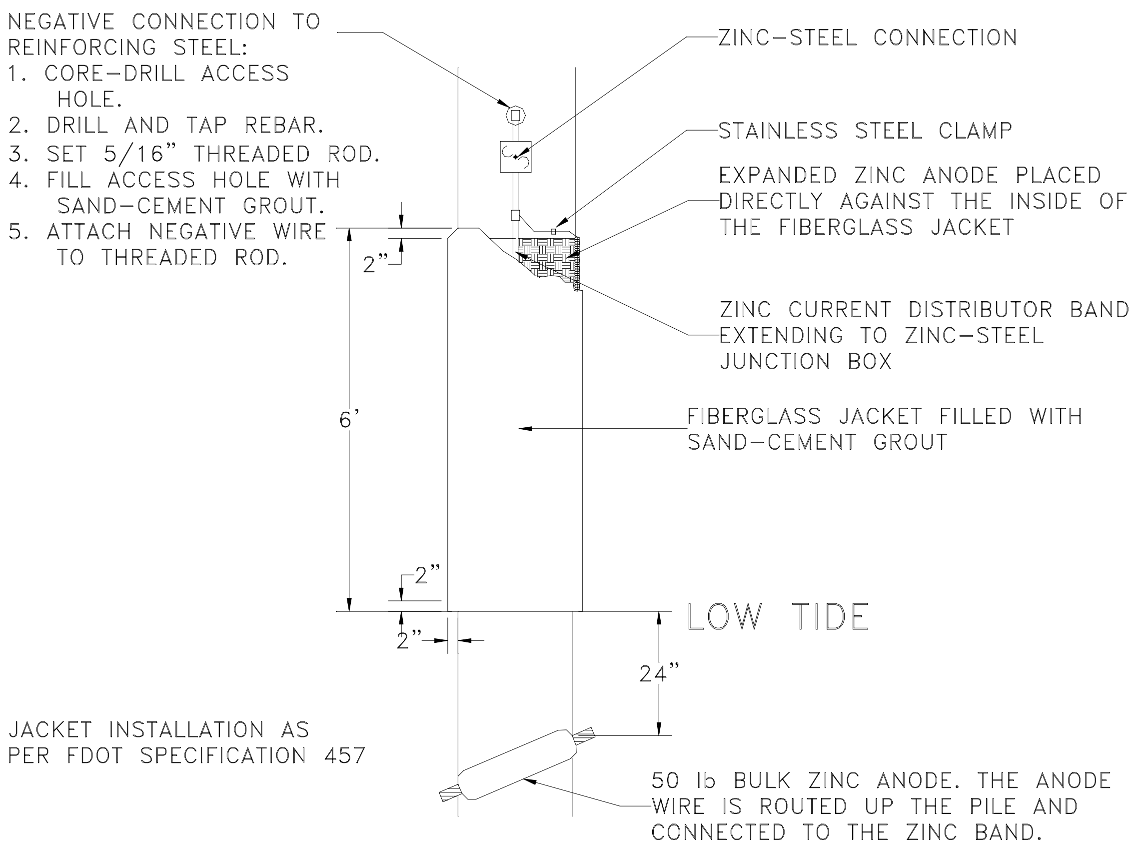
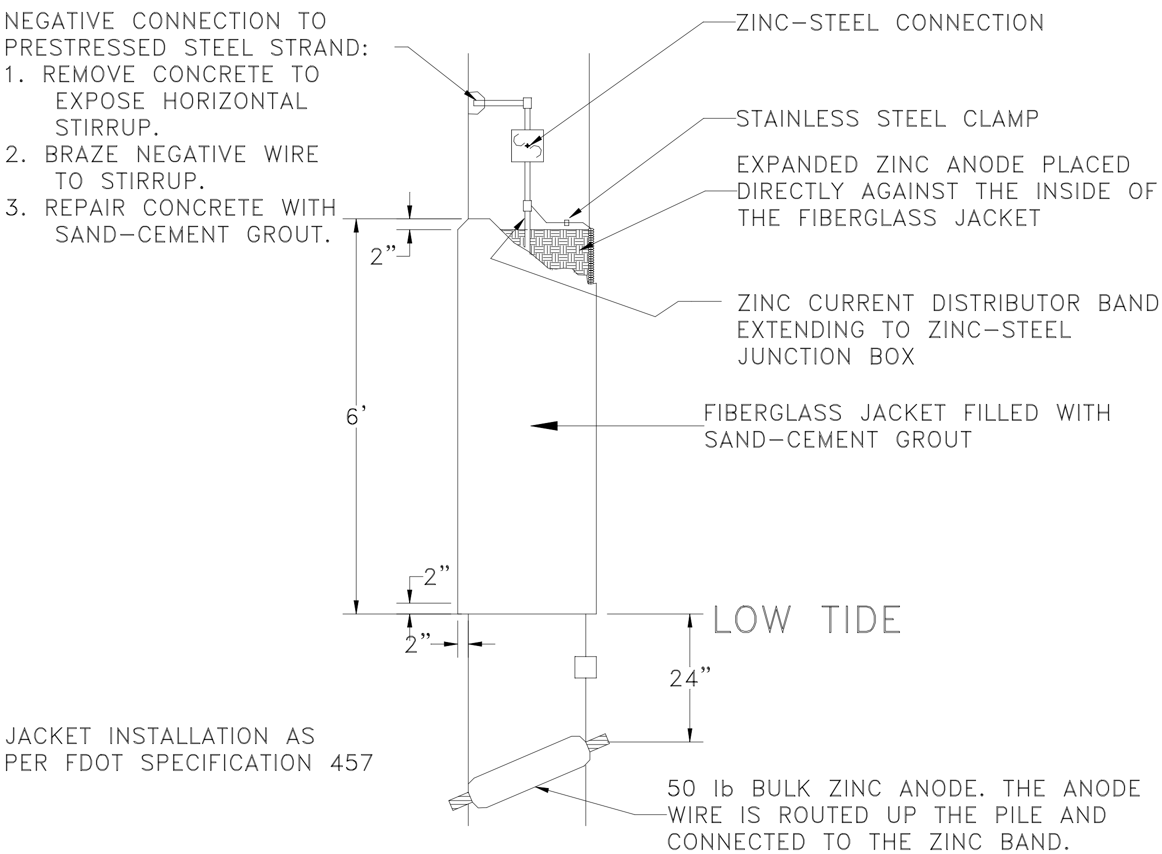
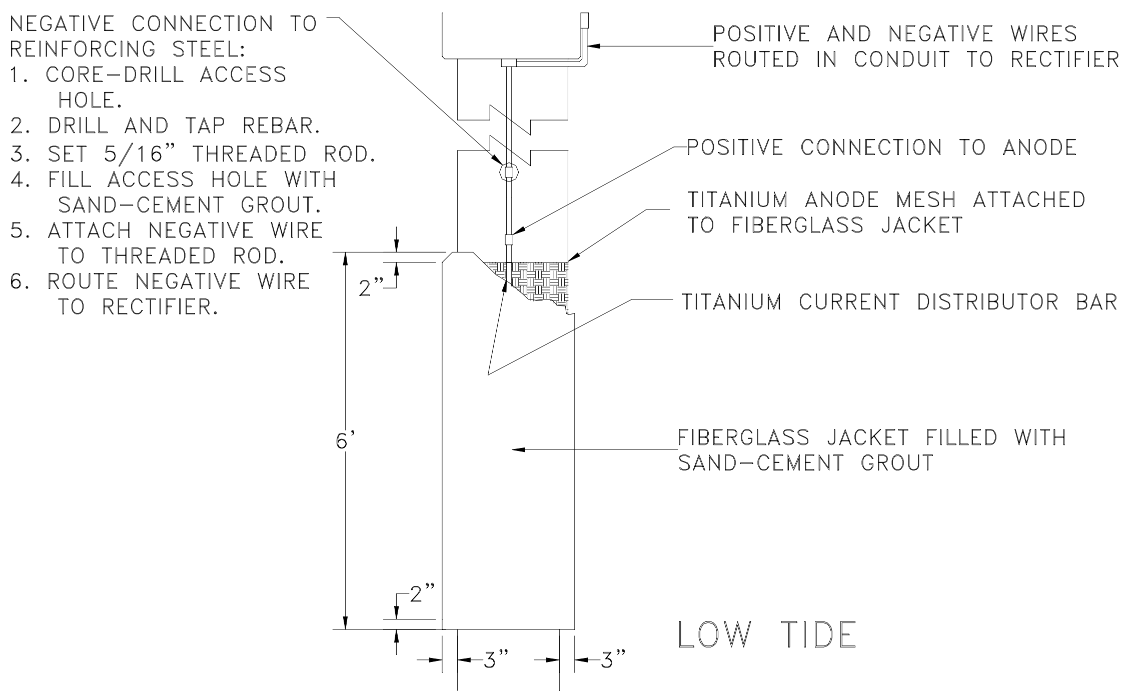


Figure 5-17
Sacrificial Cathodic Protection System Pile Jacket For Strand Reinforced Prestressed Concrete Piles



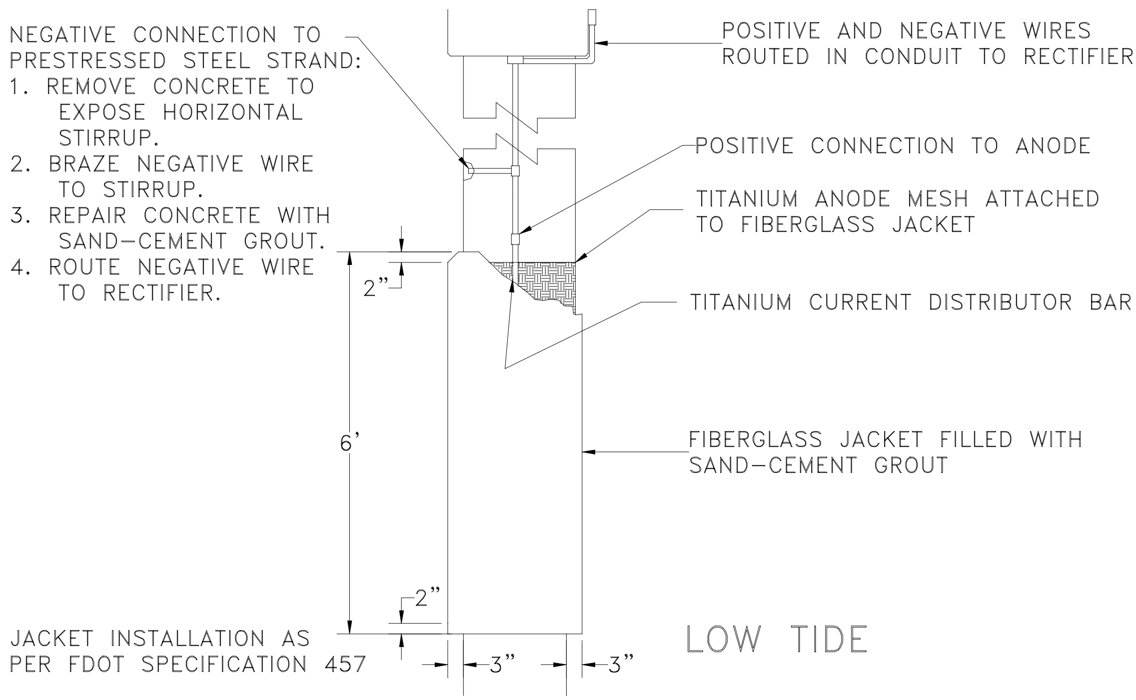
NOTE: ELECTRICAL CONTINUITY TEST MAY BE REQUIRED.

Figure 5-18
Impressed Current Cathodic Protection System Pile Jacket For Rebar Reinforced Concrete Piles



JACKET INSTALLATION AS
PER FDOT SPECIFICATION 457

Figure 5-19
Impressed Current Cathodic Protection System Pile Jacket For Strand Reinforced Prestressed Concrete Piles



NOTE: AN ELECTRICAL CONTINUITY TEST MAY BE REQUIRED.

Figure 5-20
Repair Of Sheared Concrete Beam Seat

NOTE: CONCRETE T BEAM IS SHOWN. DETAILS ARE TYPICAL FOR OTHER TYPES OF BEAMS. PAINT OLD CONCRETE WITH EPOXY PRIOR TO PLACEMENT OF NEW CONCRETE.

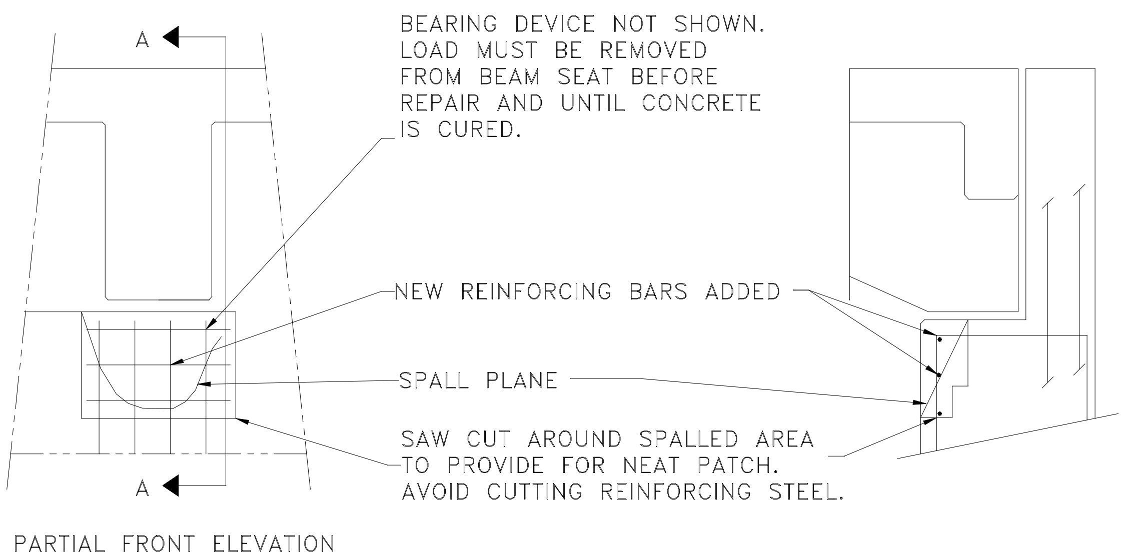
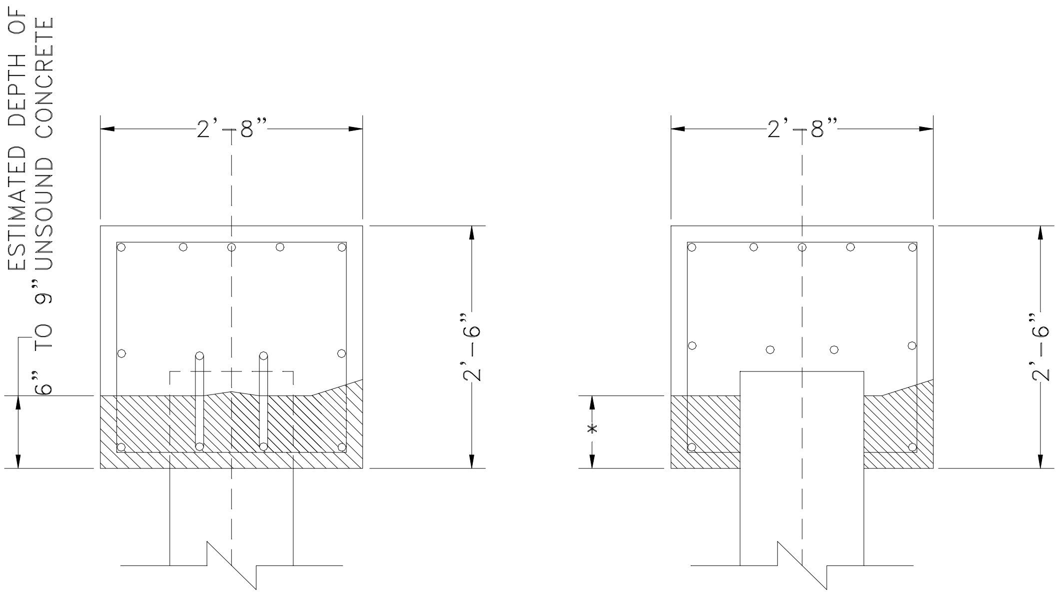


Figure 5-21
Temporary Steel Frame Support For Repair Of Pile Cap



* NOTE:
IN THE VICINITY OF PILES IF THE REMOVAL OF UNSOUND CONCRETE IS APPROACHING THE INTERFACE BETWEEN TOP PILE & CAP, THE STEEL FRAME (AS SHOWN ON DETAIL) SHALL BE PROVIDED TO TRANSMIT THE LOAD FROM THE CAP TO THE PILE BEFORE FURTHER UNSOUND CONCRETE IS REMOVED.

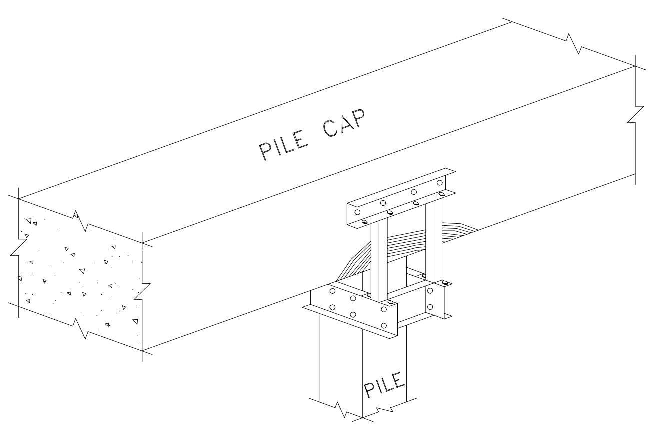


Figure 5-22A
Temporary Steel Frame Support For Repair Of Pile Cap

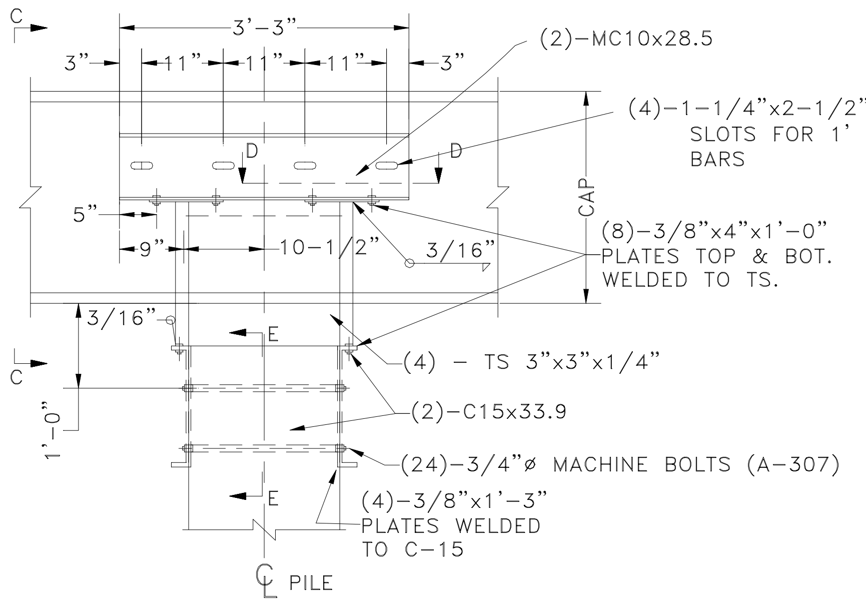
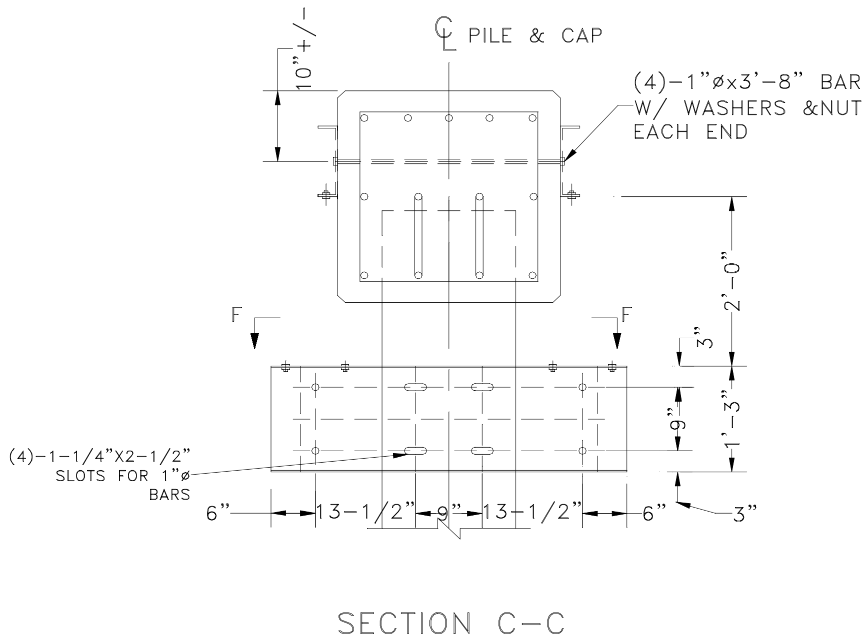


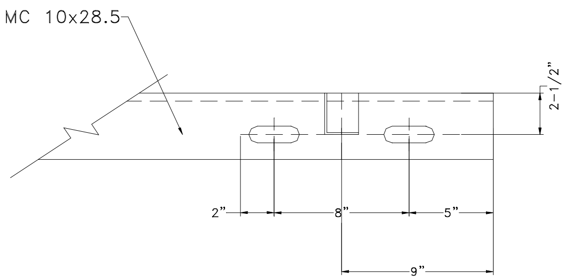
FIGURE 2

STEEL FRAME DETAIL: (SEE NOTE FOR STEEL FRAME REQUIREMENTS) THIS DRAWING & SECTIONS C. D. E & F ARE SCEMATIC ONLY.

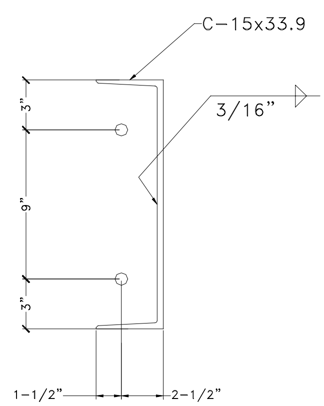


SECTION C–C

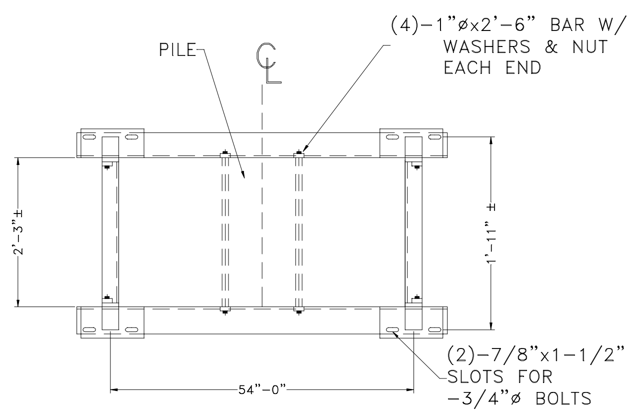
Figure 5-22B
Temporary Steel Frame Support For Repair Of Pile Cap



SECTION D–D



SECTION E–E



SECTION F–F

STEEL FRAME MATERIALS:

1. STRUCTURAL STEEL FOR FRAME AROUND PILES SHALL CONFIRM TO THE ASTM A-36 SPECIFICATIONS.
2. -3/4"ø STEEL MACHINE BOLTS SHALL CONFIRM TO THE ASTM A-307 SPECIFCATIONS.
3. 1"ø STEEL THREADED BAR SHAL CONFIRM TO THE ASTM A-307 OR A-36 SPECIFICATIONS.
4. -3/4"ø BOLTS & 1"ø RODS SHALL HAVE LOCK WASHERS AND HEXAGONAL NUTS.

Figure 5-23
Steel H-Pile Repair

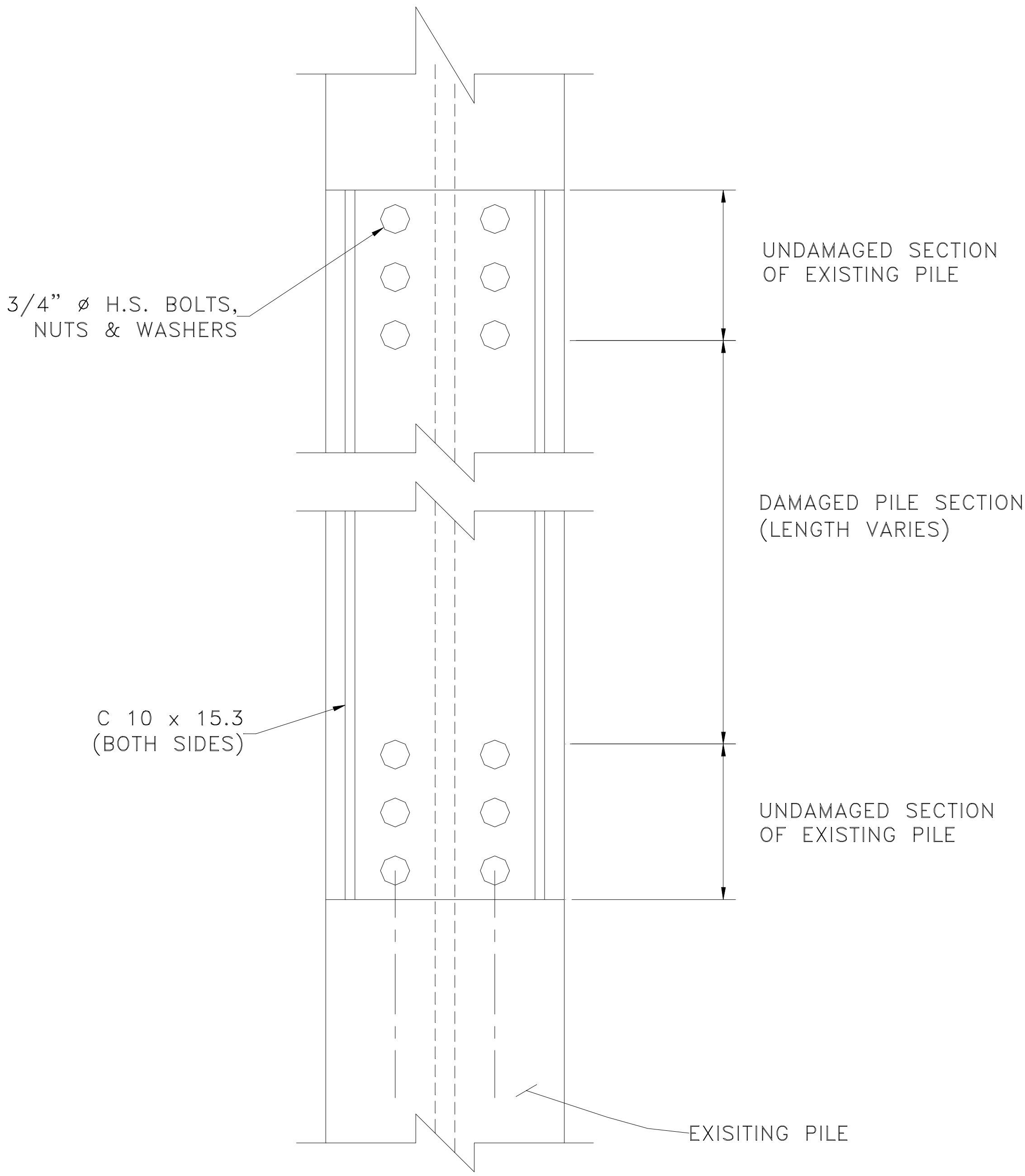


Figure 5-24
Replacement Of Damaged Or Decayed Timber Piles

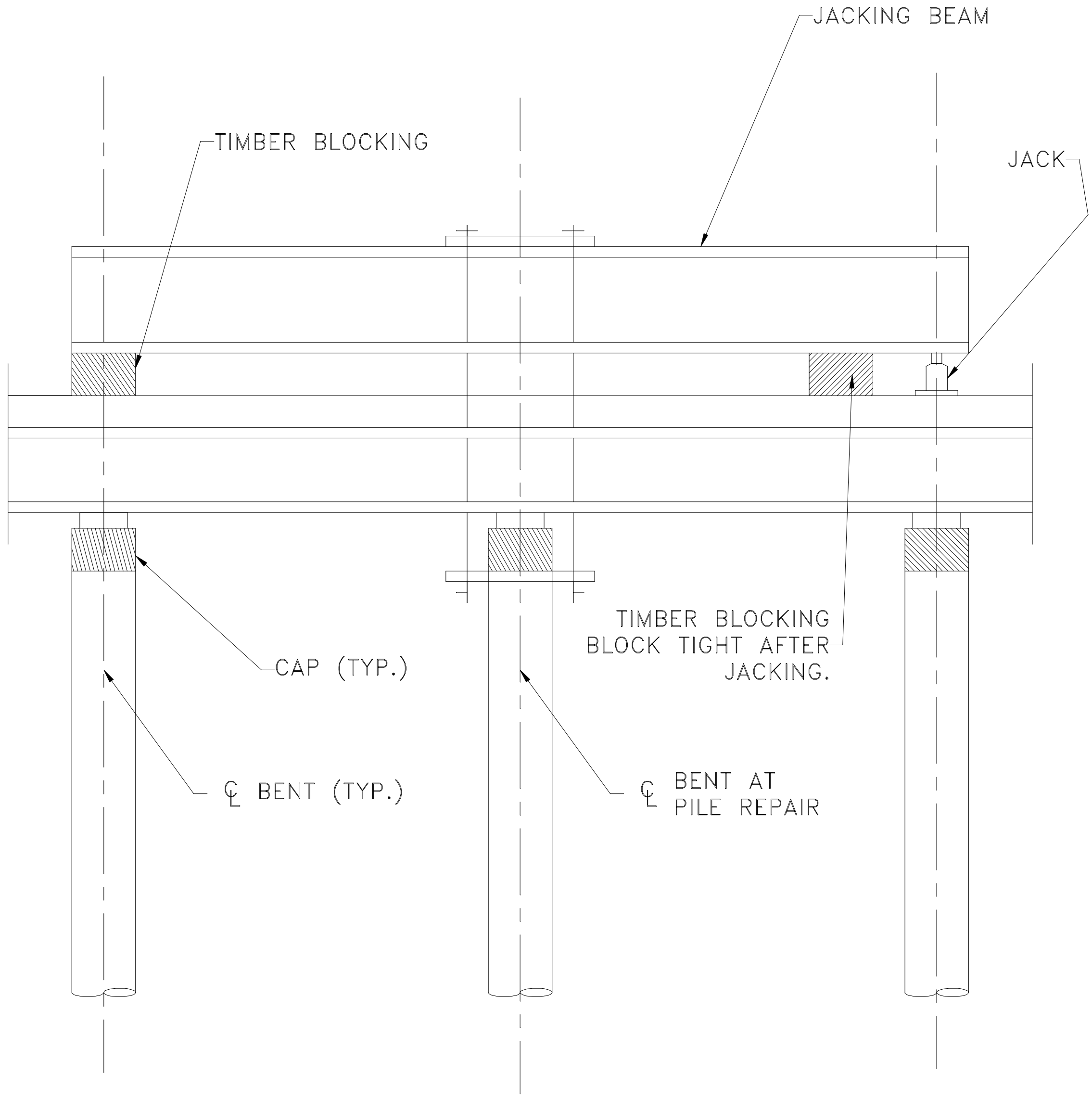


Figure 5-25
Replacement Of Damaged Or Decayed Timber Piles

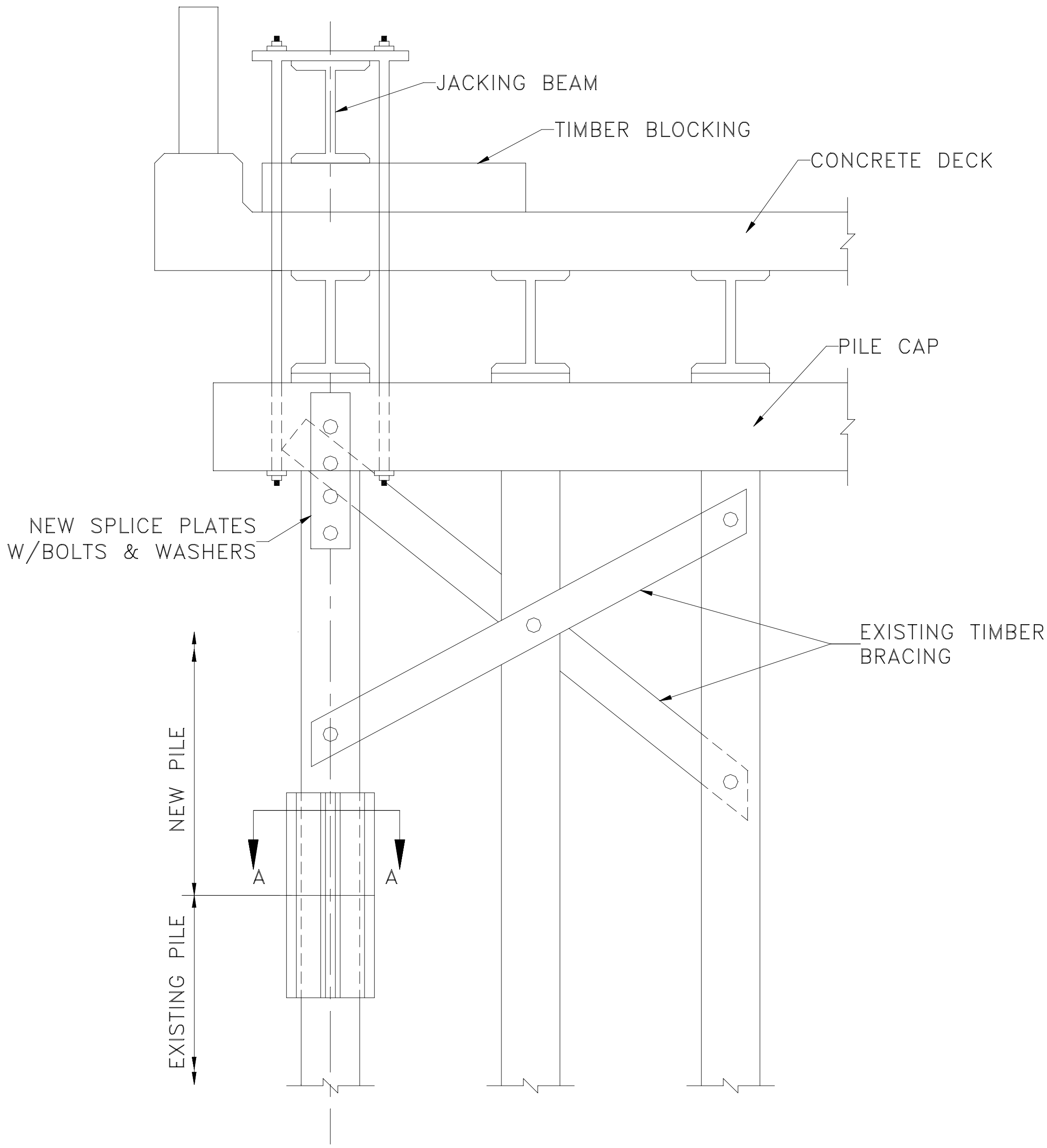


Figure 5-26
Replacement Of Damaged Or Decayed Timber Piles

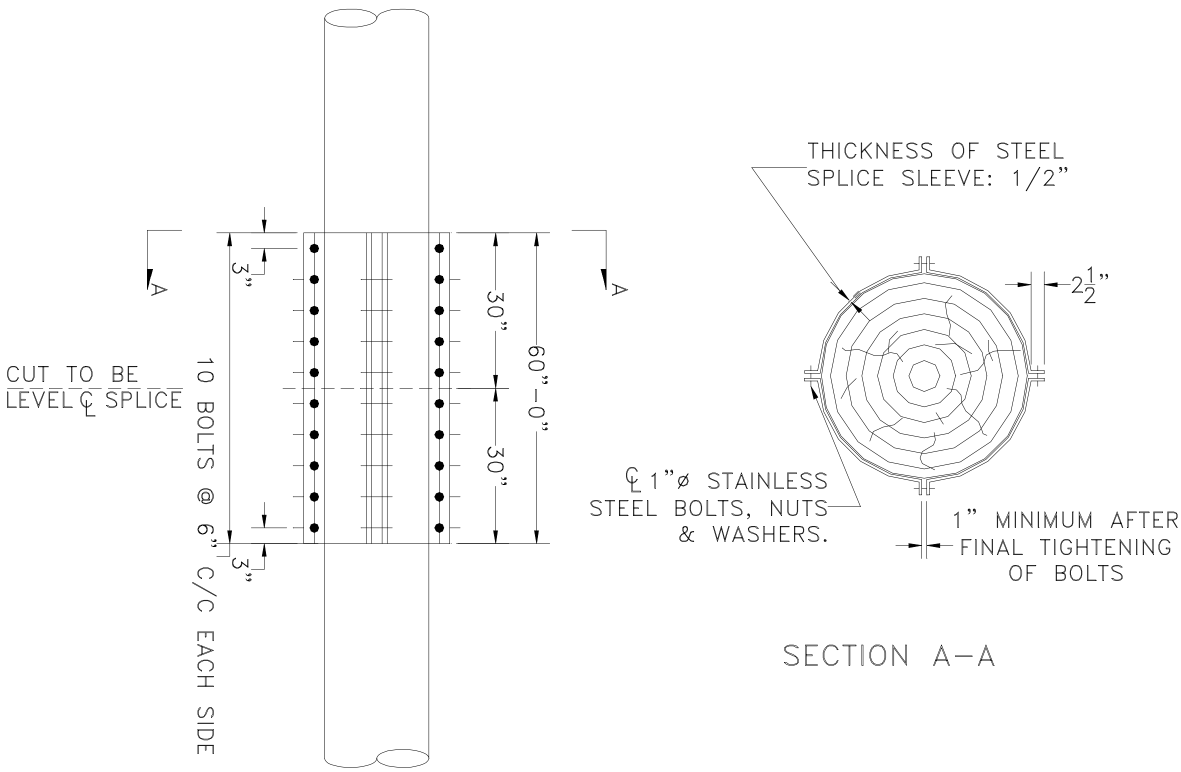


Figure 5-27
Timber Cap Replacement - Jacking From Pile Bent

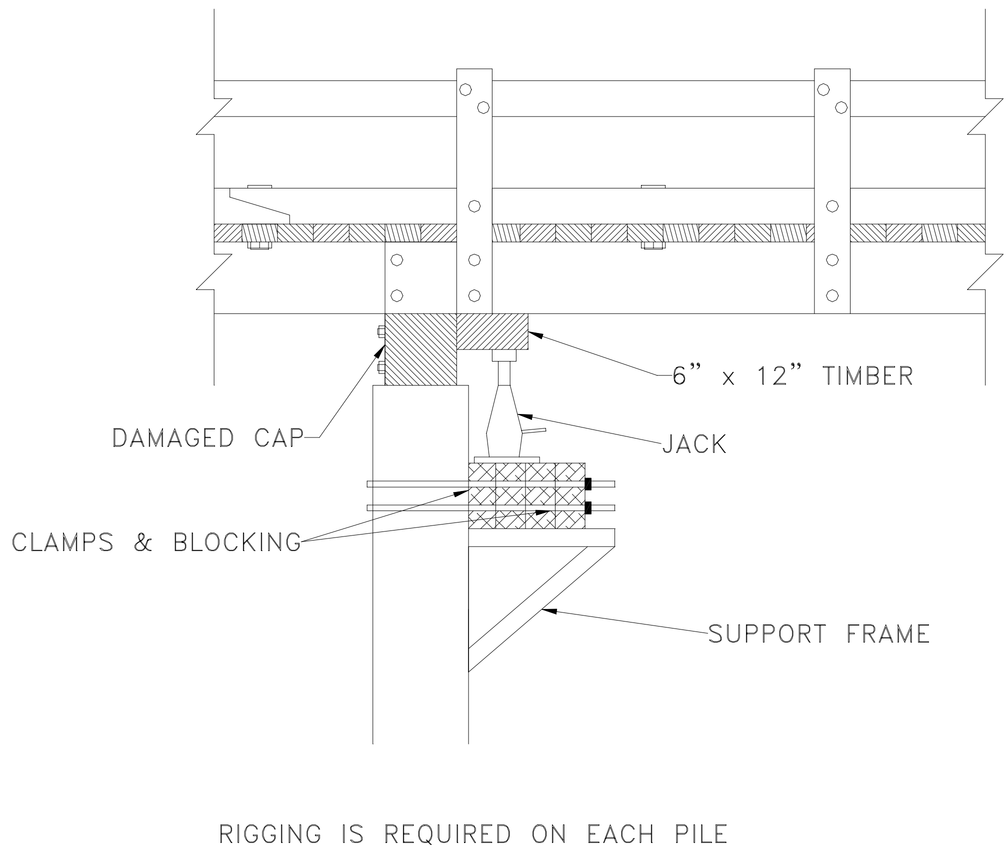


Figure 5-28
Timber Cap Strengthening

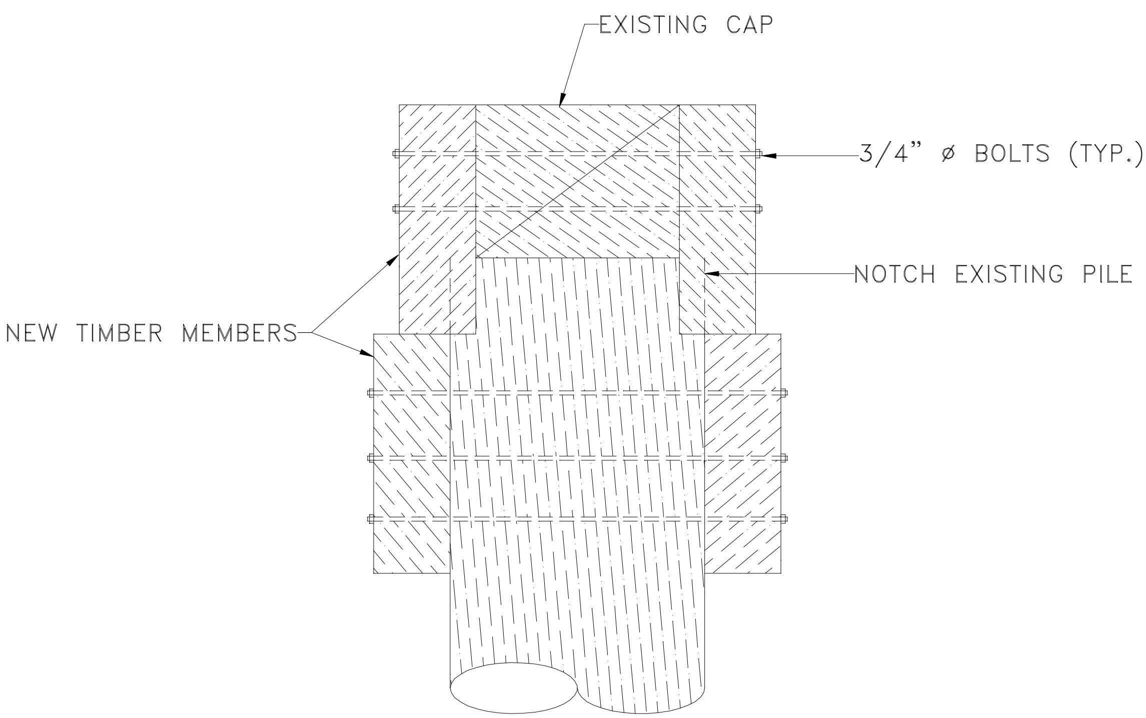


Figure 5-29
Strengthening An Existing Bent

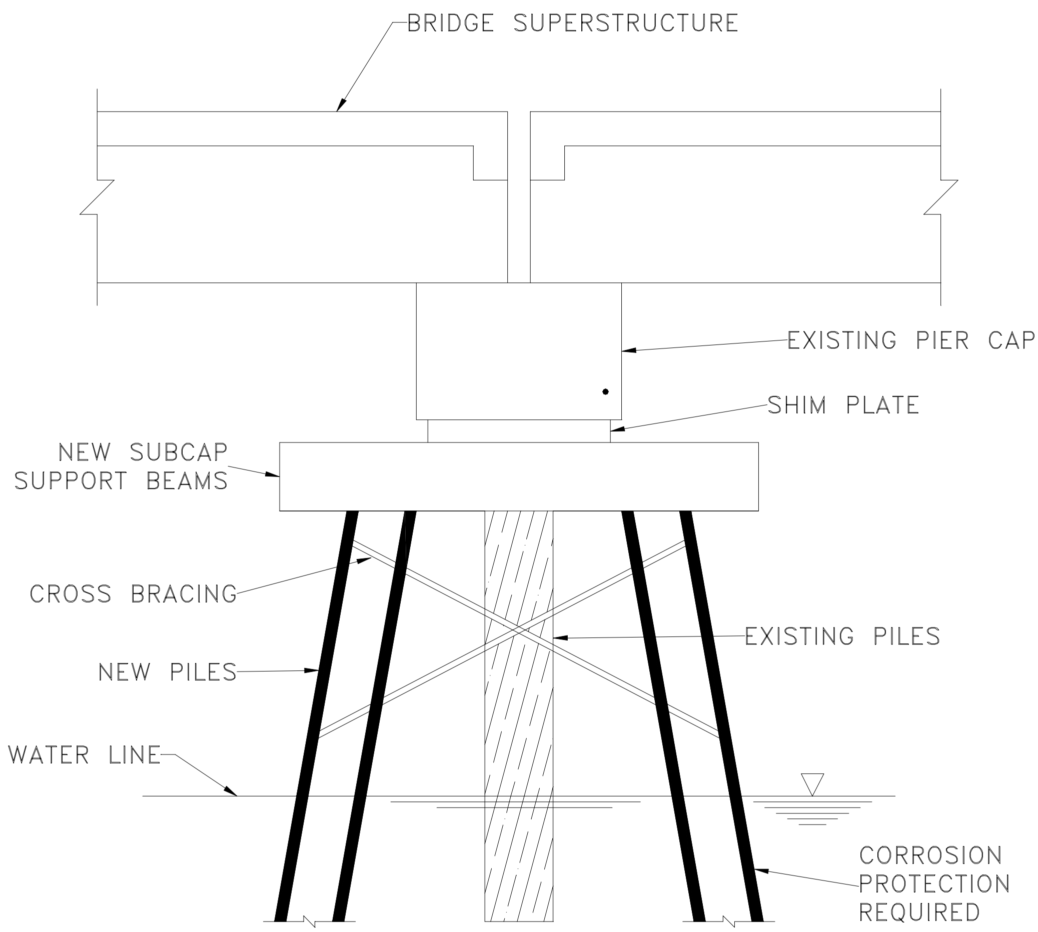


Figure 5-30
Timber Helper Bent

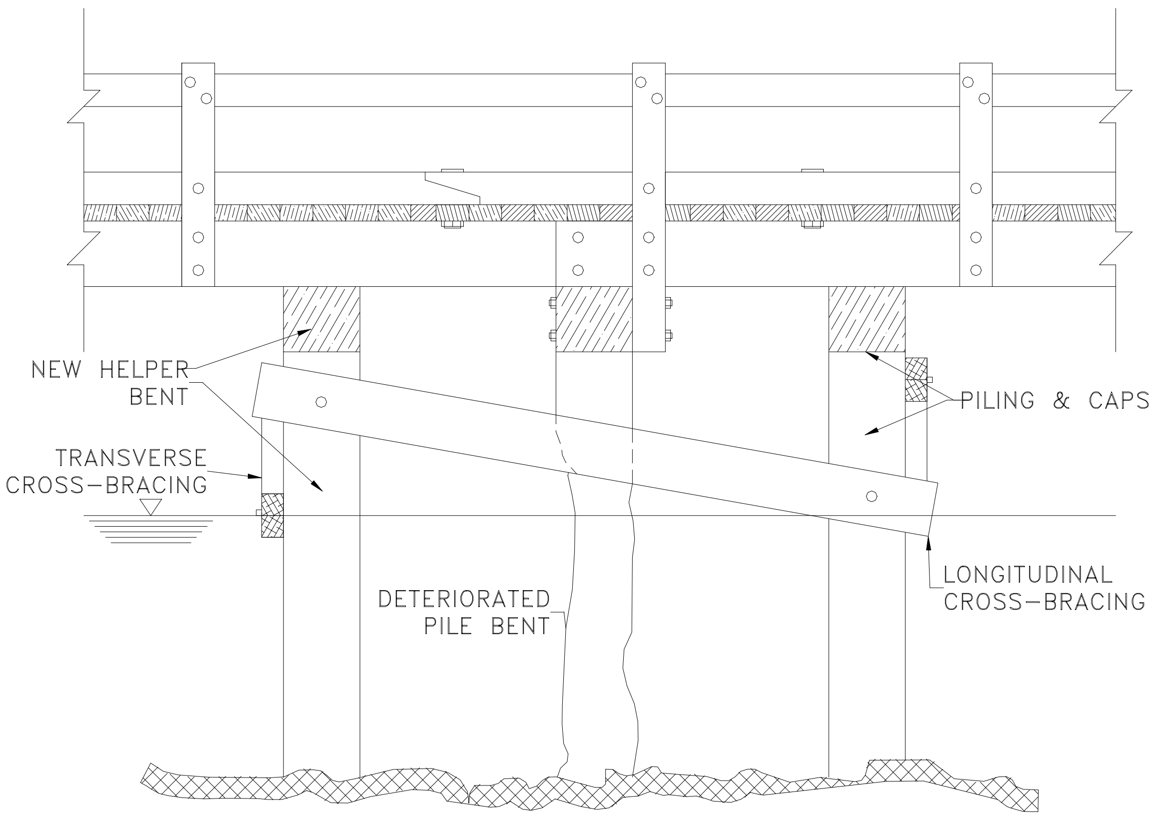


Figure 5-31
Temporary Bent

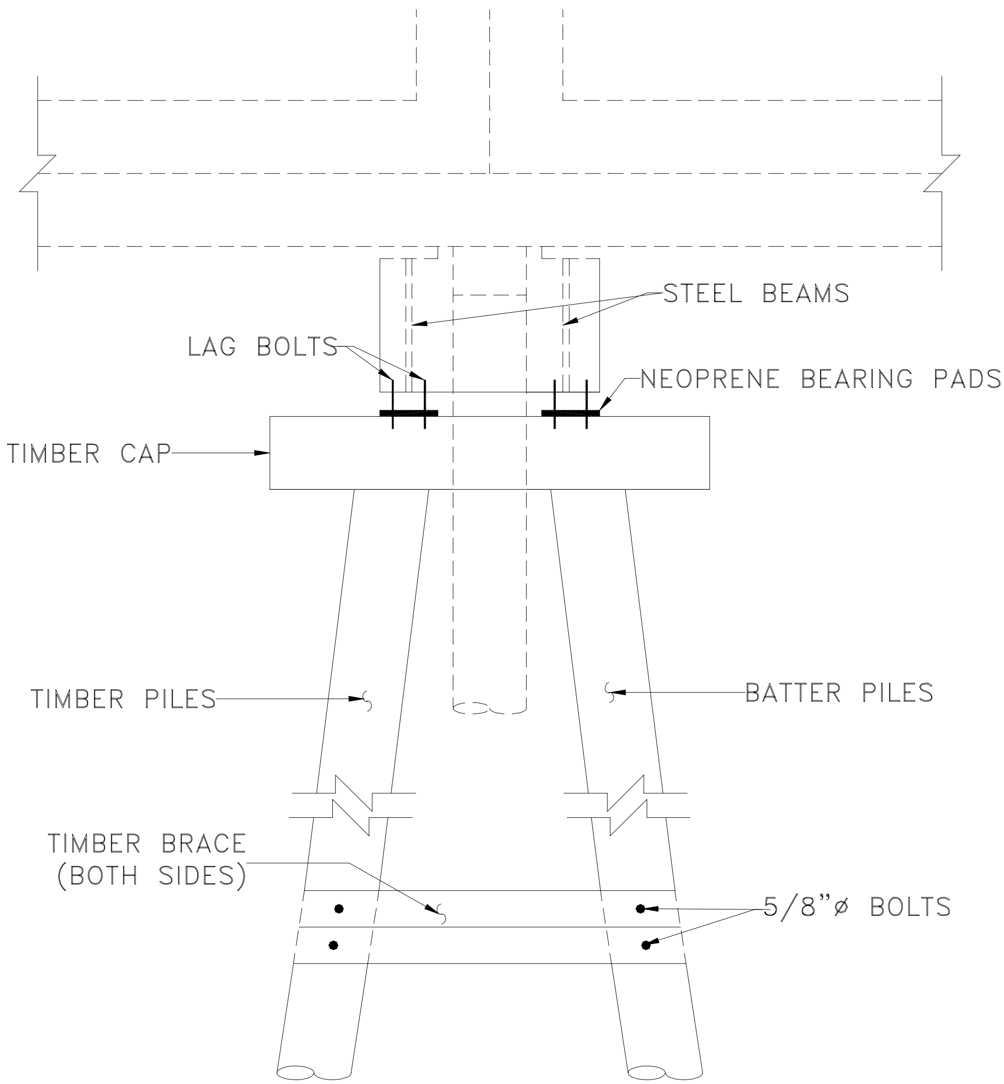


Figure 5-32
Installation of Deadman

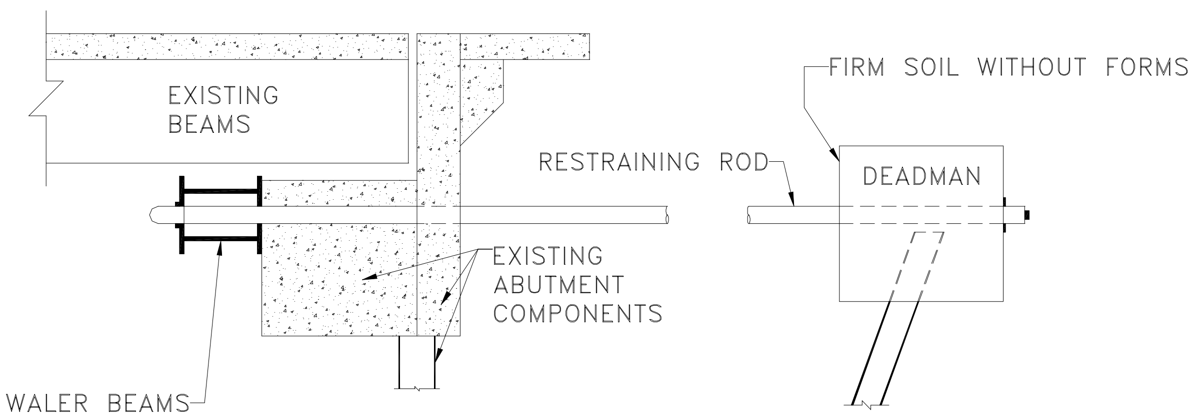


Figure 5-33
Repair of Abutment Face

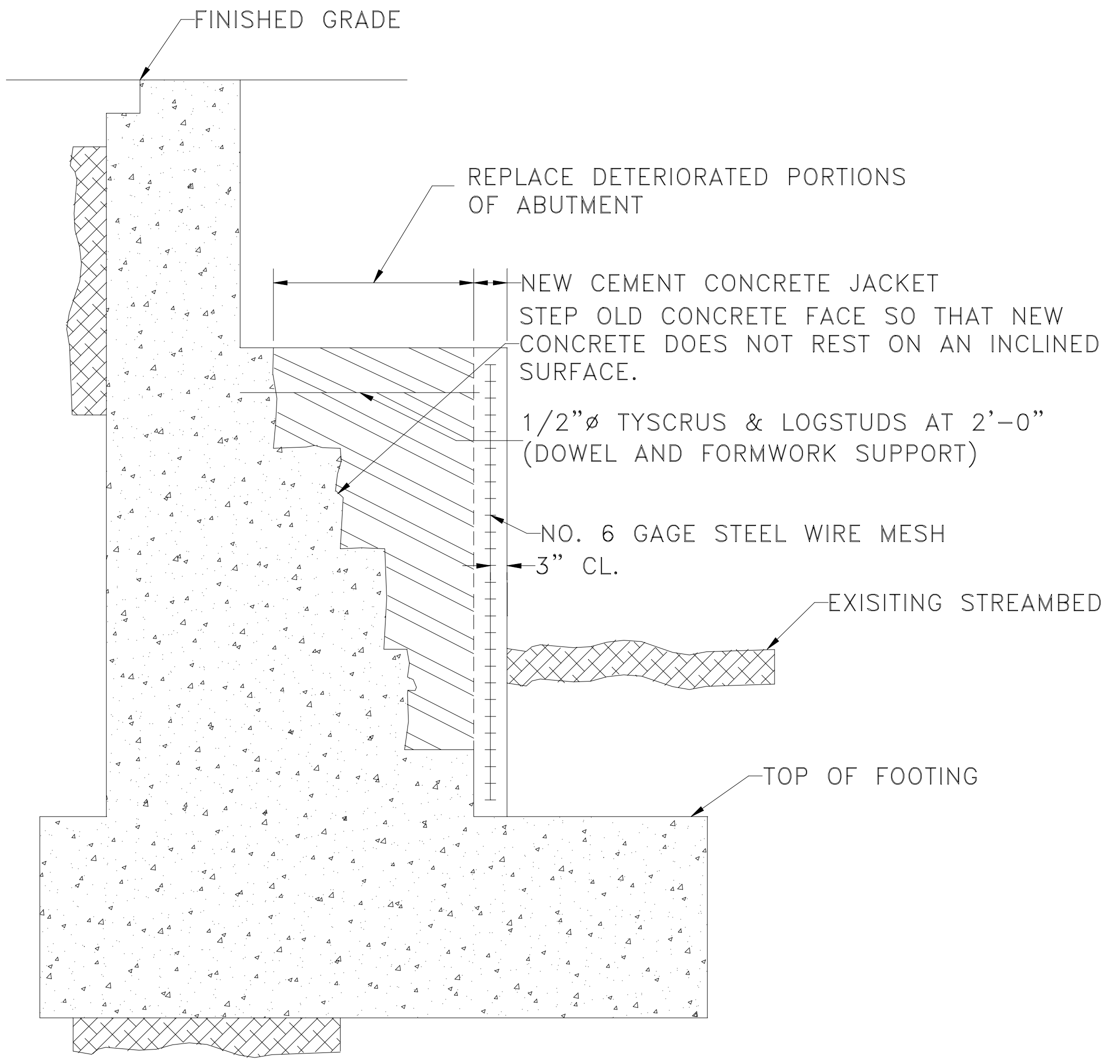


Figure 5-34
Abutment Backwall Repair

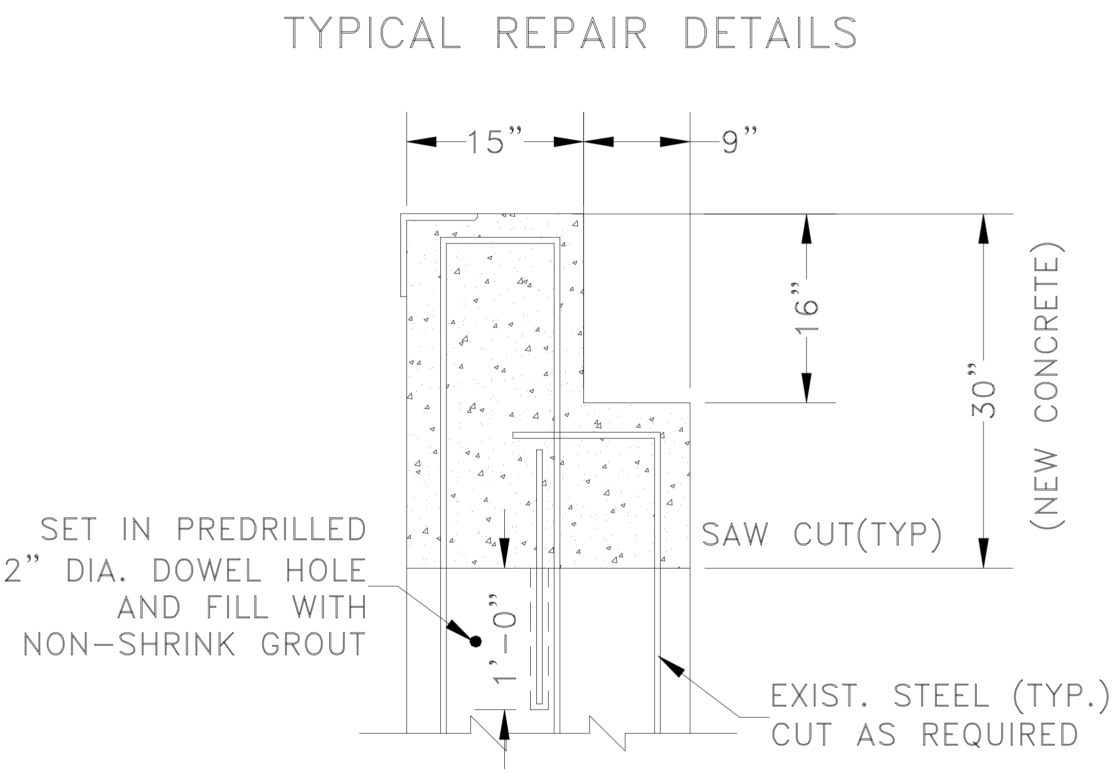


Figure 5-35
Concrete Wingwall Repair

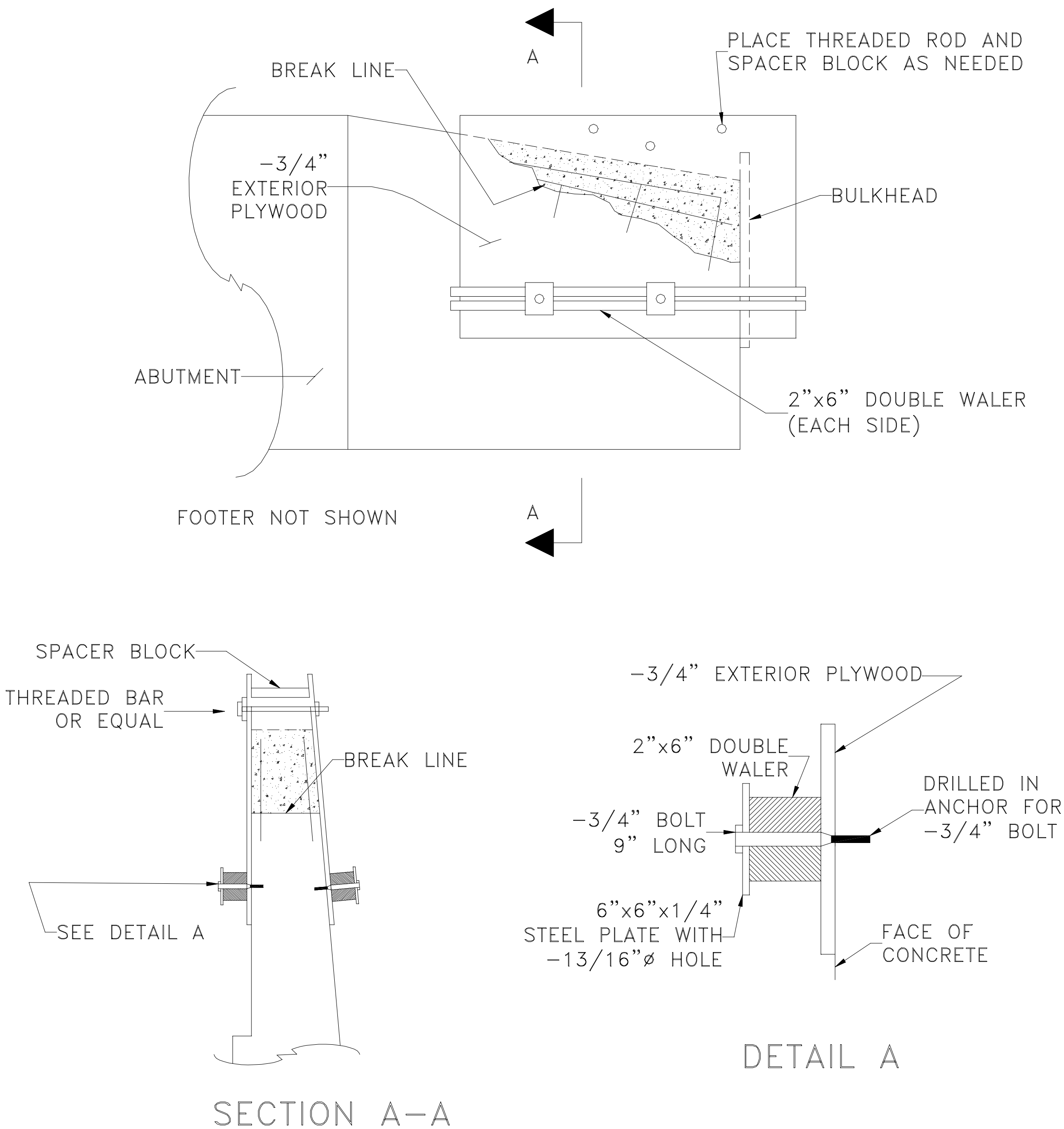
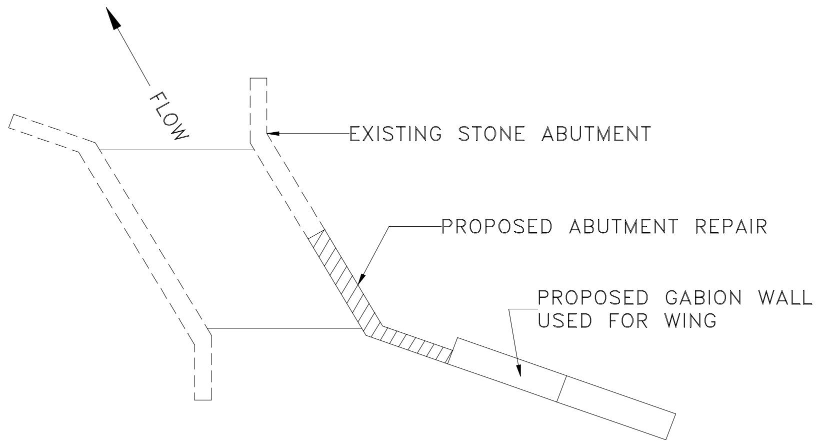
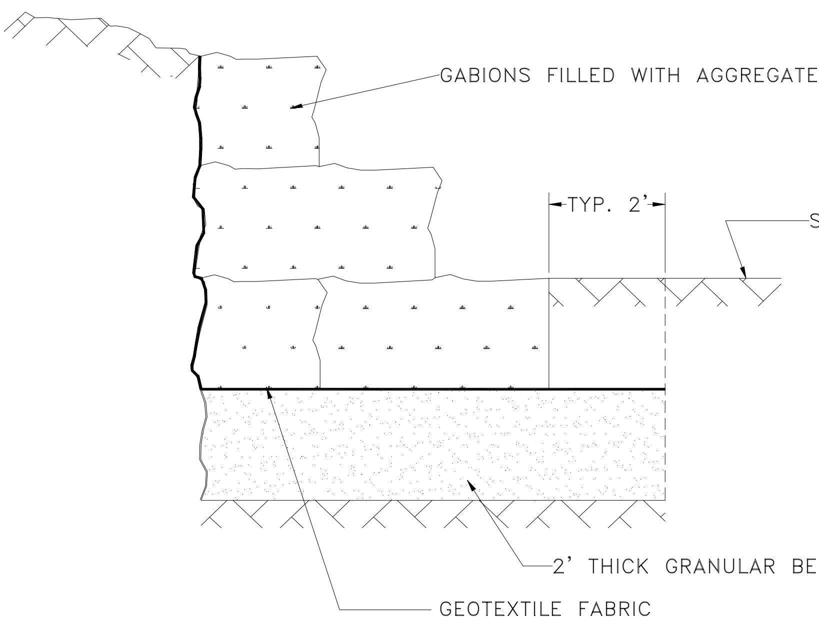


Figure 5-36
Wingwall Extension Using Gabions

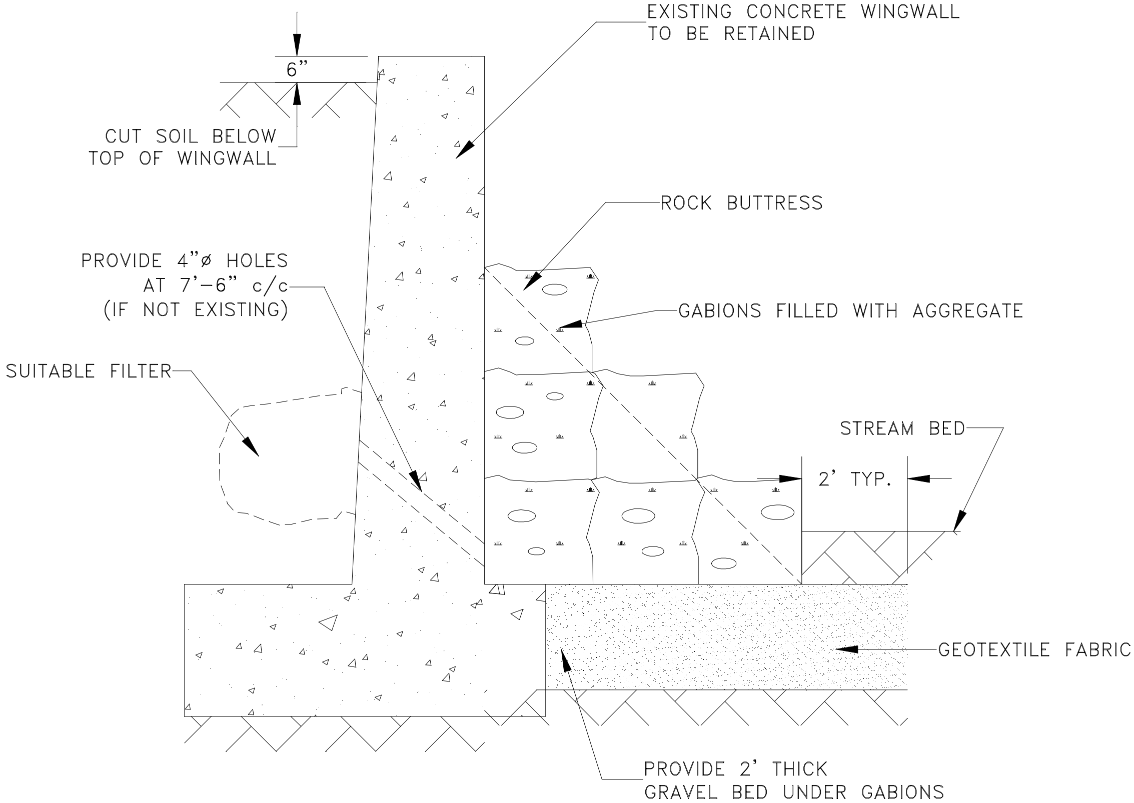


PLAN



WING WALL CROSS–SECTION

Figure 5-37
Wingwall Stabilization Using Gabions



WING WALL CROSS-SECTION

Figure 5-38
Reinforced Earth Wall Panels

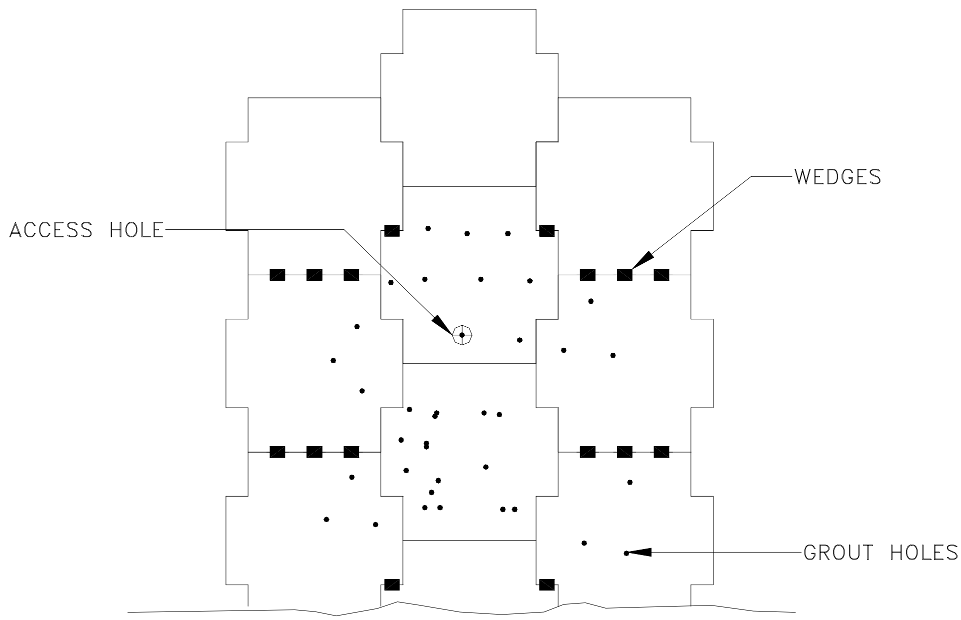


Figure 5-39
Reinforced Earth Wall - Panel Cut Diagram

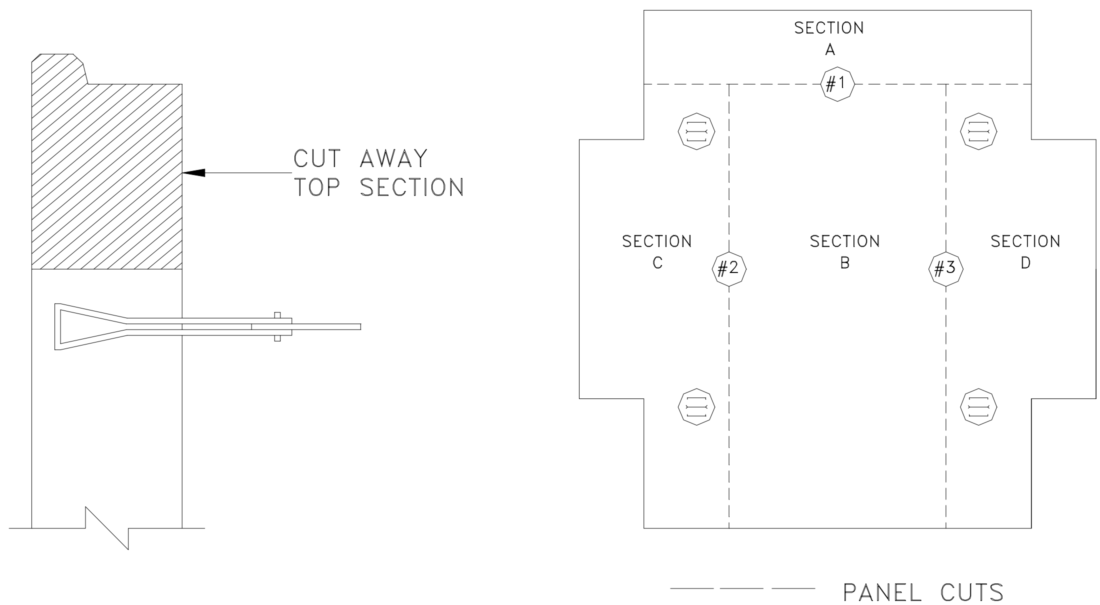
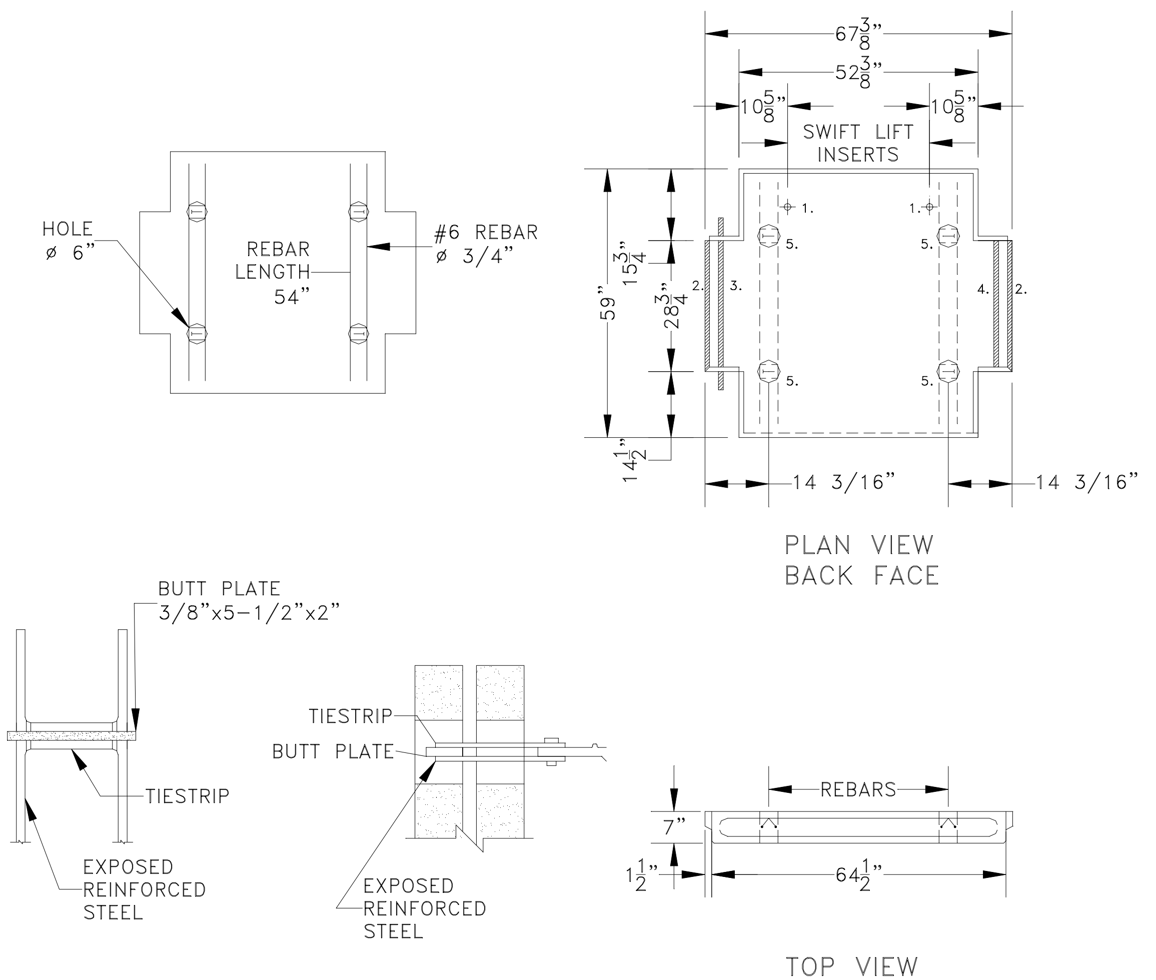


Figure 5-40
Reinforced Earth Wall - Replacement Panel Details



1. SWIFT LIFTS LOCATED ON FRONT, REAR, AND TOP OF PANELS. FRONT & REAR TO BE LOCATED 6" +/- FROM TOP.
2. DO NOT CAST LIPS THAT HAVE BEEN CROSS HATCHED.
3. NO ERECTION DOWEL REQUIRED.
4. NO PVC REQUIRED.
5. 6" ROUND HOLES TO BE MADE BY USING A CYLINDER MOLD.

Figure 5-41
Repair of Deteriorated Concrete Pier

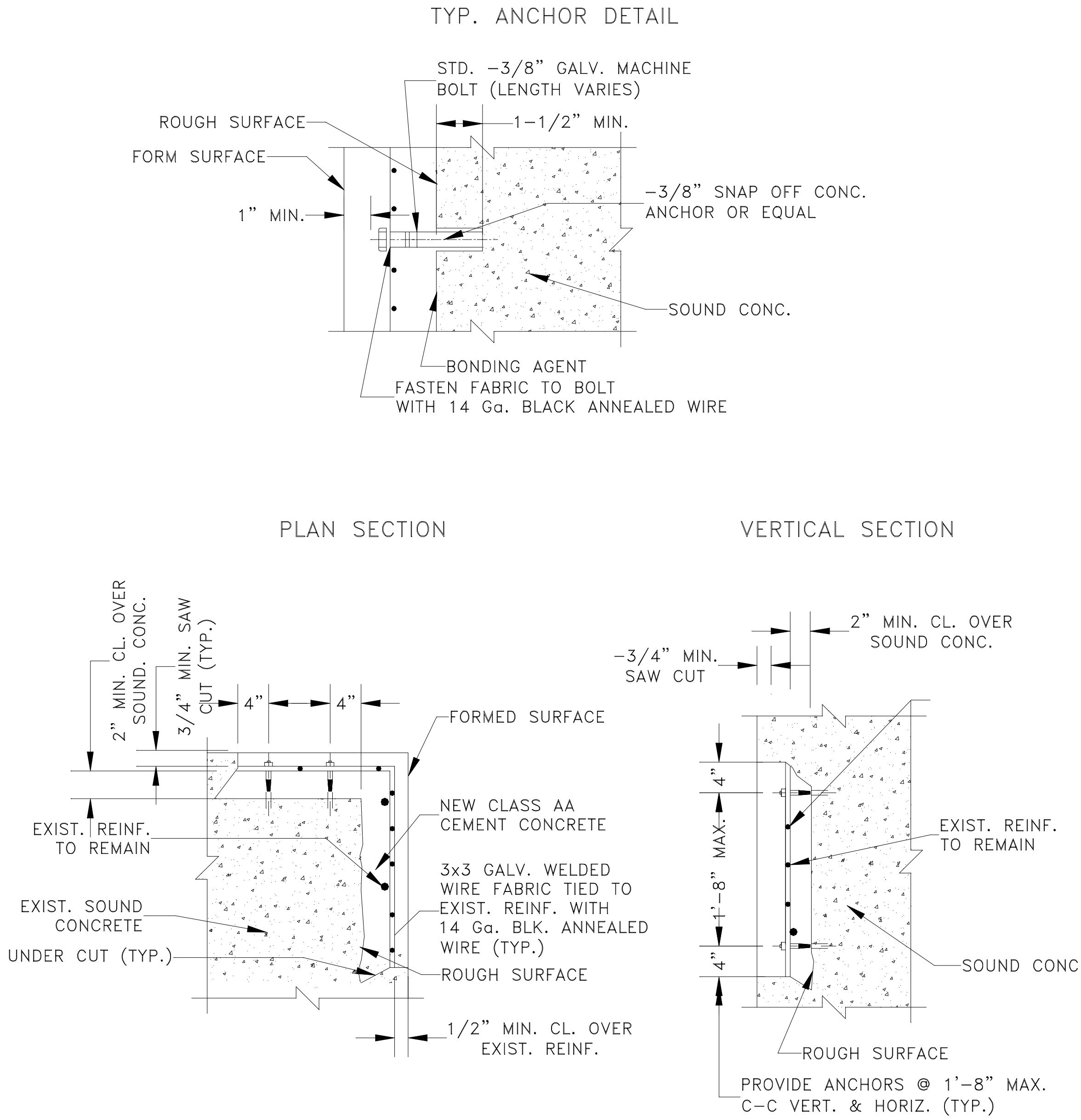


Figure 5-42
Post Tensioning of Cracked Hammer Head Pier
Plan & Elevation

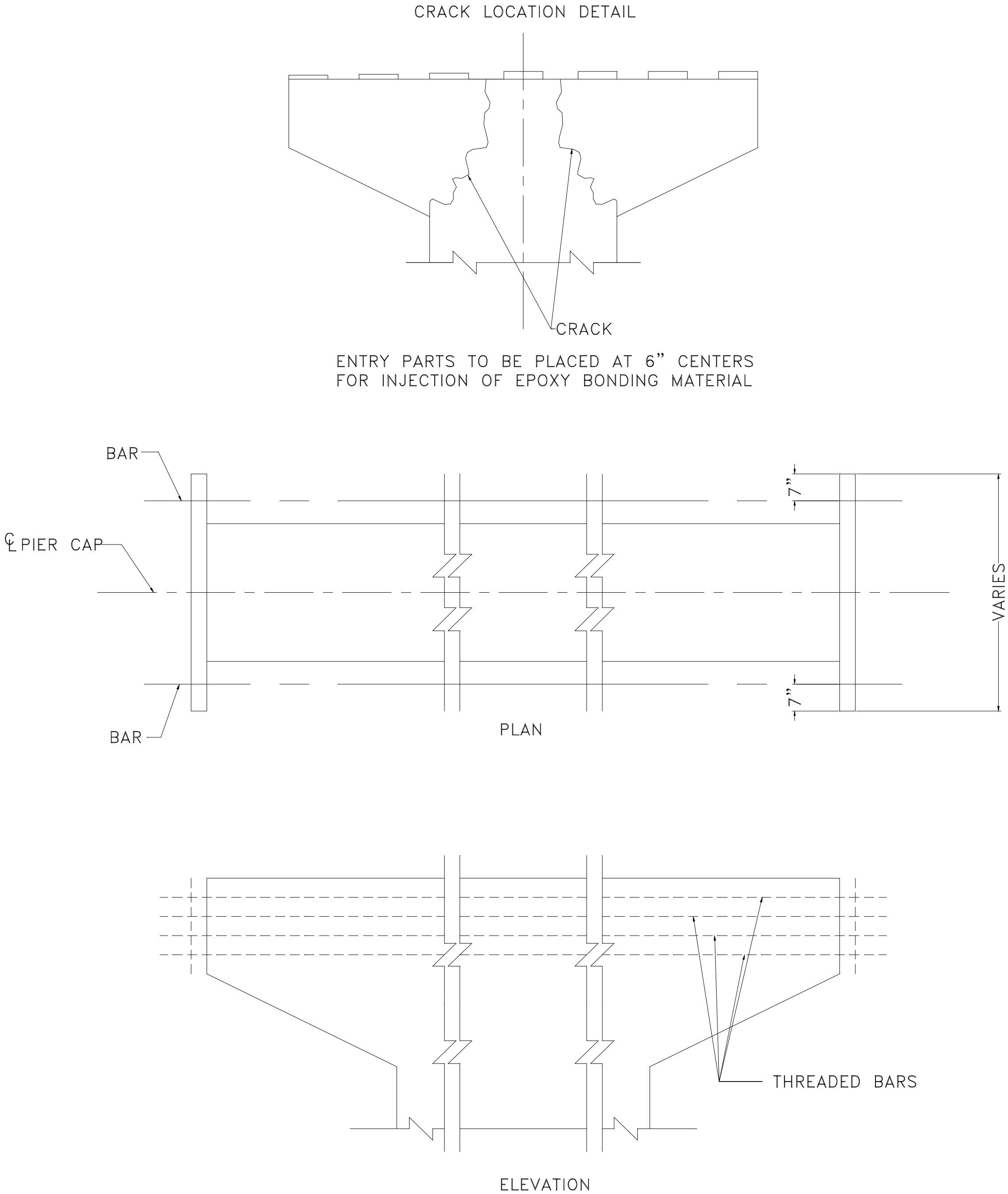
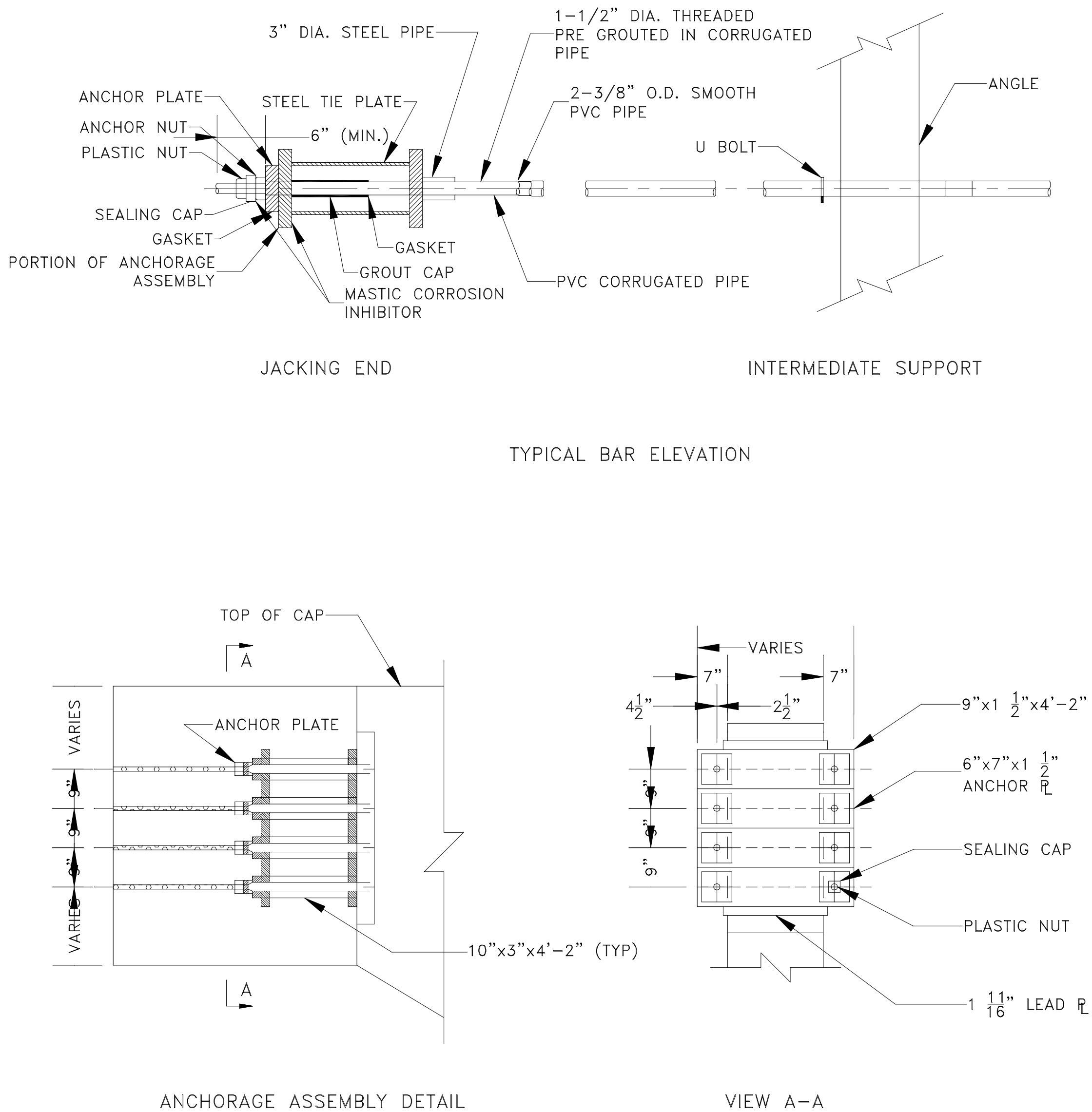


Figure 5-43
Post Tensioning of Cracked Hammer Head Pier
Anchorage Details



CHAPTER 6

CHANNELS

6.1 CHANNEL MAINTENANCE (DEBRIS & VEGETATION REMOVAL)

To remove debris that blocks flow in the channel, including: logs, brush, tree limbs, fallen trees, trash, sediment, vegetation, or large rocks and boulders. Either manual or mechanical methods should be used. Accumulation of debris in the channel can cause scour, impact, drag or other damage to the bridge structure.

Refer to the Bridge Maintenance Training Manual, FHWA-HI-94-034, Chapter XV, *Miscellaneous Maintenance Procedures*, Section B, *Debris Removal from Channel*.

6.1.1 Channel Modifications

Poor channel alignment or a restricted waterway opening may be the cause of continuing maintenance problems. Changes to the waterway channel may sometimes be necessary. Channel changes include modifications to the horizontal or vertical alignment, cross section, and roughness.

The practice of relocating waterways for better alignment is no longer permitted in most areas, and if it were permitted it would require involvement of other agencies such as the Corps of Engineers. Most changes to horizontal alignment, such as straightening a channel, will also involve a change in slope. Change in slope can result in increased scour when the slope is steeper, or an increased accumulation of sediment when the slope is flatter.

Local channel modifications in the immediate vicinity of the bridge do not always have the intended effect. Minor channel modifications in the immediate vicinity of a bridge may be effective, but should not be made without careful engineering analysis.

6.2 SCOUR PROTECTION & REPAIR

Area maintenance personnel should know the bridges that are susceptible to problems from a major storm. They are generally the first on the scene and the first to know when bank erosion is occurring, or when slope protection and flow control measures have been damaged.

Refer to the Bridge Maintenance Training Manual, FHWA-HI-94-034, Chapter

XV, *Miscellaneous Maintenance Procedures*, Section C, *Scour Protection and Repair*.

6.2.1 Slope Protection

A. Rock Riprap

Consists of graded stone (or broken concrete) placed on a prepared surface, usually with some type of filter layer between the stone and the supporting bank. Primary reasons for the failure of rock riprap include:

1. Inadequate cut-off walls and toe walls
2. Inadequate coverage of the bank
3. Inadequate size of stone
4. Erosion of the supporting soil
5. Slope failure

B. Wire Enclosed Riprap

Includes wire mattresses and rectangular wire baskets called gabions.

C. Planted Vegetation

Use in smaller streams and in combination with other types of bank protection.

D. Concrete Block Matting

Interlocking blocks with spaces for vegetation to grow between and through the blocks form flexible bank protection mats.

E. Grout Filled Bags

Empty nylon or acrylic bags are positioned like tiles then pumped full of grout, fitting snugly against each other.

F. Tetrapods

Precast concrete shapes with extending legs that interlock with adjacent units.

G. Concrete Pavement

Used for channel lining and slope protection. Often used at the downstream end of a culvert. The concrete is cast in place on a prepared sub-grade. The primary disadvantage of concrete pavement is that it is very susceptible to failure by undercutting (scour and undermining at toe and ends of the slabs). Once failure begins it is generally progressive in nature and leads to a complete failure. Sealing cracks and joints will help to prevent infiltration of water and erosion of the sub-grade. Repair of failed concrete pavement slope protection may involve the following steps:

1. Excavate for a new end wall around toe of slope to extend to below scour line or to solid rock.
2. Set up forms for end wall and place concrete.
3. Fill voids in existing sound slope protection by removing sections of protection and filling voids with crushed stone.
4. Grade and place bedding for slope wall extension.
5. Replace damaged sections, sections removed to fill voids with concrete, and place extension.
6. Fill voids in embankment and protect slopes adjacent to stone protection with large stone riprap.
7. All the joints between concrete slope protection panels and abutment/wingwalls shall be sealed by approved material.

H. Grouted Rock Riprap

The grouting prevents the rock from being displaced and provides an impervious surface. It is subject to undercutting failure, like concrete pavement slope protection.

I. Sacked Concrete

Constructed by stacking burlap, or other porous fabric, sacks filled with concrete. The concrete oozes through the burlap and cements the sacks together. In some applications the sacks are connected together with dowels driven through the sacks. Sacked concrete is also subject to undercutting after major storms. Repair damaged sections as follows:

1. Remove all loose or damaged sacks of sand-cement materials.
2. Replace and compact selected fill material.
3. Replace and stabilize sand-cement sacked material.
4. Tamp and wet material for permanent set and cure.

J. Concrete-Filled Fabric Mats

Synthetic fabric mats are filled by pumping concrete or grout into the mat in the field.

K. Bulkheads

Vertical walls used to protect the embankments and approach roadway fill. Failure of bulkheads is generally due to undermining, erosion of fill material behind the bulkhead or lack of foundation support. Maintenance involves repair of erosion at the base of the bulkhead, keeping weep holes open, and repairing cracks or other types of damage that might occur.

6.2.2 Flow Control Measures

Flow control or stream training measures control one or more of the following characteristics: direction of flow, velocity of flow, and depth of flow. See Figure 6-1.

A. Spurs

A linear structure that projects into the channel from the stream bank or embankment. Other names for a spur are jetty, groin, deflector, and wing dam. Common materials for constructing spurs are rock and earth embankments, timber piles, steel piles and sheet piles. Some spurs are fence-type structures, designed to allow water to flow through.

B. Retards

Similar to spurs except that they are parallel to the direction of flow and are used to correct alignment problems or used at curves to keep flow from striking a bank directly.

C. Dikes

Used on flood plains to control the flow of water that overflows the banks.

D. Spur Dikes

A projecting dike at the upstream side of the bridge designed to shift scour effects from the abutment to the end of the spur dike.

E. Jack Fields

Installed along the channel bank to collect debris.

F. Check Dams

A low dam or weir built across the downstream channel.

6.2.3 Undermining Repairs

Most repairs for scour around bridge piers and abutments will involve the placement of the eroded material. In many cases both riprap and concrete will be used. There are several precautions that apply to the placement of these materials around bridge substructure units.

A. Riprap

The following factors should be considered when placing riprap around piers or abutments:

1. Care must be exercised when dumping riprap around existing structural units. The large stones required can easily chip or break the concrete elements. Placement of riprap around piers must often be done from a barge.
2. Placement should be made in even lifts to avoid unbalanced loads on the footings.
3. An engineering analysis should be performed to ensure that footings or piles supports will not be overloaded.
4. The stone must be of suitable size for the anticipated flow conditions.
5. Riprap should not extend above the original stream bed. The turbulence resulting from riprap improperly placed around a pier can cause localized scour at other piers or at the abutment.

B. Concrete

Placement of concrete to repair scour or undermining of substructure units usually requires either dewatering or underwater placement of concrete. In either case proper placement, good forms, and skilled personnel are essential. Dewatering may be accomplished by constructing cofferdams, or if environmental regulations permit, diversion of the flow away from the repaired area. The primary disadvantage of dewatering with cofferdams is the clearance required for driving sheet piling. General precautions for concrete placement under wet or dry conditions include:

1. An engineering analysis should be performed to ensure that pile support will not be overloaded.
2. Forms should be prevented from moving and should not be removed prematurely. Pre-bagged concrete or concrete pumped into fabric forms are often used in place of conventional forms.
3. Concrete should not be placed in running water or be allowed to drop through water as this could wash the cement out of the concrete.
4. Underwater placement can be accomplished by underwater tremie, pumping, bagged concrete, and prepacked concrete.

6.3 DOLPHINS & FENDER SYSTEMS

Repair the fender system for collision damage from marine traffic; repair bolts and cables for looseness and corrosion, broken parts and missing hardware; replace fender parts as required.

A. Recommended Method

1. Locate work platform or work barge as needed.
2. Remove all damaged or deteriorated timber and/or cables.
3. Erect new timbers and/or cables and drive new piling to conform with "Standard Fender Details" (see figures). Extract deteriorated or damaged pile where practical or drive new pile adjacent to existing pile and pull into desired position.
4. All wood and cables shall be treated for preservative that comply with the requirements of the Department of Environmental Regulations.
5. Plastic-impregnated and coated wire rope is recommended for this repair method.

6.4 SEAWALLS

Inspect concrete components for scaling, cracking, spalling and rust stains from exposed steel; also check for scour and erosion or any evidence of settlement or movement. Severe conditions should be corrected immediately. Unsound concrete should be removed, reinforced steel cleaned and new concrete placed.

6.4.1 Stop Seawall Movement by Tie-back System

Install tie-back system to provide horizontal resistance to wall movement. This method is not feasible if structure exists behind the wall. The seawall cannot be straightened to its original alignment without excavating behind it. This method only stops further movement.

A. Recommended Method

1. Install new wales below high water.
2. Excavate trenches behind wall, normal to the line of wall.
3. Extend trenches at elevation of new wale behind wall far enough to be out of active zone of earth pressure.
4. Place tie rods from wale to end of trench.
5. Place concrete at end of tie rod to form deadman anchor.
6. Backfill the trenches.
7. This method shall be designed by a geotechnical engineer.
8. This tie-back system can also be used on concrete seawall.
9. In selection of the backfill material, the wave action and erosion shall be considered as an important factor.

6.4.2 Stop Seawall Movement by Changing Soil Loading

Stopping of seawall movement by replacement of normal fill behind the wall with lightweight fill and by adding riprap at the outside of the toe of the wall. This method may not be used if the depth of water at face of wall is important and lightweight aggregate is expensive or not available.

A. Recommended Method

1. Dump stone riprap against toe of wall to decrease unsupported length of wall and to add passive soil resistance.
2. Remove backfill from the area of active earth pressure and replace with lightweight aggregate fill.
3. The construction procedure should be designed by geotechnical engineer.

6.4.3 Repair Damaged Seawall by New Tie-back Wall

Replaces damaged seawall with new tie-back wall giving combined system of equal or greater strength. No need to excavate behind existing wall. This repair method is only suitable where grouted soil anchorage can be secured in existing soil. The new wall with its own tied-back system becomes independent and the old wall is no longer needed.

A. Recommended Method

1. Drive new steel sheet piling in front of existing damaged seawall.
2. Drill hole for prestressed tie rod and pipe casing through both walls into stiff clay out of active zone behind old wall.
3. Pressure grout inside casing forming bulb in clay at end of casing and apply prestress force on the tie rod.
4. Pressure grout the void between the casing and tie rod.
5. Fill space between old and new sheet piling with concrete.

6.4.4 Repair Seawall by Patching and Pressure Grouting

Patching holes in seawall on the front side and pumping grout behind the wall on the backside. Patching and grouting together seal holes in wall and prevent further leaching of backfill. Technique for testing and grouting requires experience and diligence.

A. Recommended Method

1. Patch and cover the holes accessible from outside.
2. Test for location of unknown leaks or holes by driving pipe casings behind wall and pump water or air through casings.
3. Pump cement/water grout into succeeding pipe casings until indication at each pipe that ground behind wall and holes in wall are sealed.
4. This repair method can be used to repair timber, steel or concrete seawalls.

Figure 6-1
Hydraulic Training Structures